Luxor

The Search for a Hashprice Floor – or Downside Resistance

A Hashrate Supply and Demand Model

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We want to start by thanking Gaurav Budhrani and Christian Lopez for reviewing our work and providing insightful feedback to improve it.

Introduction and Summary

As Bitcoin Hashprice reaches all-time lows, driven by increases in network difficulty and decreases in Bitcoin's price, miners are feeling the pain, investors are searching for bargains, and everyone is looking for the bottom.

This led the Luxor team to hypothesize about a hashprice floor – a minimum hashprice where declines in Bitcoin's price are offset by reductions in the network difficulty from unprofitable miners turning off their operations.

To evaluate this hypothesis, we constructed a supply and demand model of bitcoin mining hashrate and hashprice. Our hope is that the model will give Bitcoin miners and financial market participants insight into hashrate and hashprice mechanics: to help with capital investment and allocation, downside risk analysis and hedging decisions.

Given the proportional relationship between block times, network hashrate and difficulty, we used the full-pay-per-share (FPPS) mining pool payout formula to construct a downward sloping hashrate demand curve. It represents the hashprice miners can expect to earn for different levels of network hashrate with fixed block subsidy, transaction fees, and bitcoin price. To estimate an upward sloping hashrate supply curve, we used public filings, news releases, Luxor's internal database and other available research to determine ASIC manufacturers' historical and future production volumes and the profitability distribution of miners across the network. **The supply curve represents the overall amount of hashrate that miners are willing to supply to the network at various hashprices.**

Our model suggests:

- There is no hashprice floor as hypothesized. No matter how many miners come offline and how much network difficulty decreases, the corresponding increase in hashprice could be overcome by a potentially larger fall in the price of Bitcoin. That is to say – the hashprice floor is zero.

- However, our model indicates there are areas of what we call hashprice resistance. As Bitcoin's price falls and our demand curve moves to the left, there are regions where hashprice falls less per unit drop in the price of Bitcoin.

- In 2022[1], our model indicates more hashprice resistance between a Bitcoin price of $6,000 - $24,000, with resistance strongest in the $12,000 - $18,000 range. While in 2023[2], our model indicates more hashprice resistance between $8,000 - $30,000, with resistance strongest between $14,000 - $24,000.

[1] Assuming constant block subsidy and transaction fee
[2] Assuming constant block subsidy and transaction fee

- It should be noted that hashprice resistance is marginal compared to the concept of a hashprice floor. Our model does not predict any situation where meaningful declines in Bitcoin's price can be totally offset by reductions in network difficulty. There are only minor variations in how much declines in network difficulty can offset declines in Bitcoin's price.

Further, our model can also be used for other purposes, namely:

- It can be used to better understand how bitcoin mining economics work and compare outcomes under various assumptions. In this paper, we apply three Bitcoin price scenarios to evaluate how corresponding shifts in demand could impact equilibrium hashrate and hashprice at the end of 2022 and 2023.

- It can be used to gauge a miner's competitiveness. As with any competitive market, producers of hashrate with lower marginal costs will be better positioned to withstand bear markets. Where a miner is positioned on the supply curve will determine their competitiveness in Bitcoin mining.

- It could be used as a starting framework for more refined analysis and accurate forecasting, and it can also serve as an input for capital investment decisions. For example, miners could model future cash flows under various bitcoin price scenarios. This analysis could inform capital allocation decisions, such as determining whether new expansion projects or miner purchases provide acceptable returns.

- Perhaps most importantly, the model could be used to assess financial risks and make hedging decisions. It is worth keeping in mind, there is no hashprice floor. Every miner is vulnerable to price declines at some point. Miners could use this model to explore the use of hedging instruments, like Luxor's Hashprice NDF, to build a more defensible business in a highly cyclical industry.

Now, our model's results must be interpreted with tremendous caution.

It is a mathematical representation of a system designed to further our understanding of how Bitcoin mining economics work and compare directional outcomes under various assumptions – not a completely accurate detailed mapping of the entire Bitcoin mining economy, or a forecast / prediction for the future. Different assumptions will produce different results. Further, in reality, external forces are always changing: Bitcoin prices, monetary policy, market conditions, and transaction fees to name a few, but the list goes on. The real world has more complexity than any model could ever hope to capture. Equilibrium is an abstract concept – in reality, things are always in flux.

Background on Hashrate and Hashprice

Hashrate is an important metric for the Bitcoin network and Bitcoin miners. At the technical level, hashrate is the speed at which a computer completes an operation in a cryptocurrency's code, and it is measured in hashes per second. At the blockchain level, hashrate is the underlying digital commodity that powers and secures proof-of-work cryptocurrencies such as Bitcoin. In essence, Bitcoin miners are compensated directly by the blockchain, or indirectly by a mining pool, which acts as an international market for the computing power miners produce and deliver.

Common Units of Hashrate		
Units	**Conversion**	**Typical Usage**
TeraHash per second	1 TH/s = 1 trillion hashes/s	Single ASIC or small fleet of ASICs
PetaHash per second	1 PH/s = 1,000 TH/s	Mid-to-large ASIC fleets
ExaHash per second	1 EH/s = 1,000 PH/s	Large fleets and references to the entire network hashrate

Hashprice, a term coined by Luxor in 2019, is a measure of the true value a miner gets paid for hashrate – the commodity they produce. Luxor's Bitcoin Hashprice Index quantifies the expected value of 1 PH/s of hashrate per day on the Bitcoin Network.

There is a common misconception that Bitcoins are the underlying commodity produced by miners, because their activities result in the creation of newly minted coins and is often compared with traditional gold mining. However, this confuses what miners produce with how they are compensated for that production.

Bitcoin miners produce hashrate, and hashprice (the compensatation they receive for that hashrate) is determined by four factors: the block subsidy, transaction fees, network difficulty, and Bitcoin's price. The higher the block subsidy, transaction fees, and Bitcoin's price, the higher the hashprice and vice versa for lower hashprice. Network difficulty works in the opposite direction: the more mining on the network, the smaller the slice of network rewards a miner gets.

An Economic Model for Hashrate and Hashprice: Supply and Demand

Supply and demand is the most fundamental economic model and forms the theoretical basis of modern economics. It says that the price and quantity of a commodity is determined by the interaction of supply and demand in the market. While Bitcoin mining is no doubt a new business endeavor, with peculiar characteristics and novel mechanics, we contend that it follows the same old laws of supply and demand.

In contrast to a typical commodity market with standard buyers, demand for hashrate comes from the blockchain in the form of the block reward. Bitcoin miners have the option of delivering hashrate directly to the blockchain if they are self mining, or indirectly through a mining pool. In return, they receive a share of the bitcoin block subsidy and transaction fees, which have a U.S. dollar equivalent market price. The share they receive is determined by bitcoin's difficulty adjustment mechanism – the higher the network hashrate, the higher the network difficulty, the lower the share of total rewards for each unit of hashrate, resulting in a lower hashprice and vice versa. Hence, all else being equal, miners can expect the bitcoin they receive for each hash to decline as more hashes are delivered to the network.

With several different cost profiles on the supply side, there is an overall amount of hashrate that miners are willing to supply to the network at various hashprices. Theoretically, all else being equal, miners should be willing to provide more hashrate the higher hashprice goes to capture excess profits. Conversely, the lower hashprice goes, the more miners should be unprofitable, shut off operations, and reduce hashrate.

These are undoubtedly simplifying assumptions. However, these basic assumptions allow us to construct supply and demand curves, like the ones used to analyze all other industries, and draw directional inferences about the current and future economics of Bitcoin mining.

Constructing the Demand Curve: Miner Payouts

Demand curves are a graphical depiction of the relationship between the price and the quantity demanded of a commodity. In general, they are downward sloping – that is, the higher the price of a commodity, the less it in demand by the market; and the lower the price of the commodity, the more it is in demand.

In Bitcoin mining, the market demand curve for hashrate can be represented by the formula mining pools use to payout miners, minus pool fees. Since Bitcoin mining is a stochastic process, full pay per share ("FPPS") mining pools are able to calculate the expected value and pay miners upfront for their hashrate.

$$Hashprice_{USD} = \frac{1}{d_h} \times (b_h + \frac{1}{n}\sum_{i=0}^{n-1} t_{h-i}) \times BTC_{USD\ Spot\ Price} \times (\frac{1e15 \times 86{,}400}{2^{32}})$$

Where,

h = latest block height
d = network difficulty
b = block subsidy
t = transaction fees
n = 144 = lookback period (number of blocks) included in the index

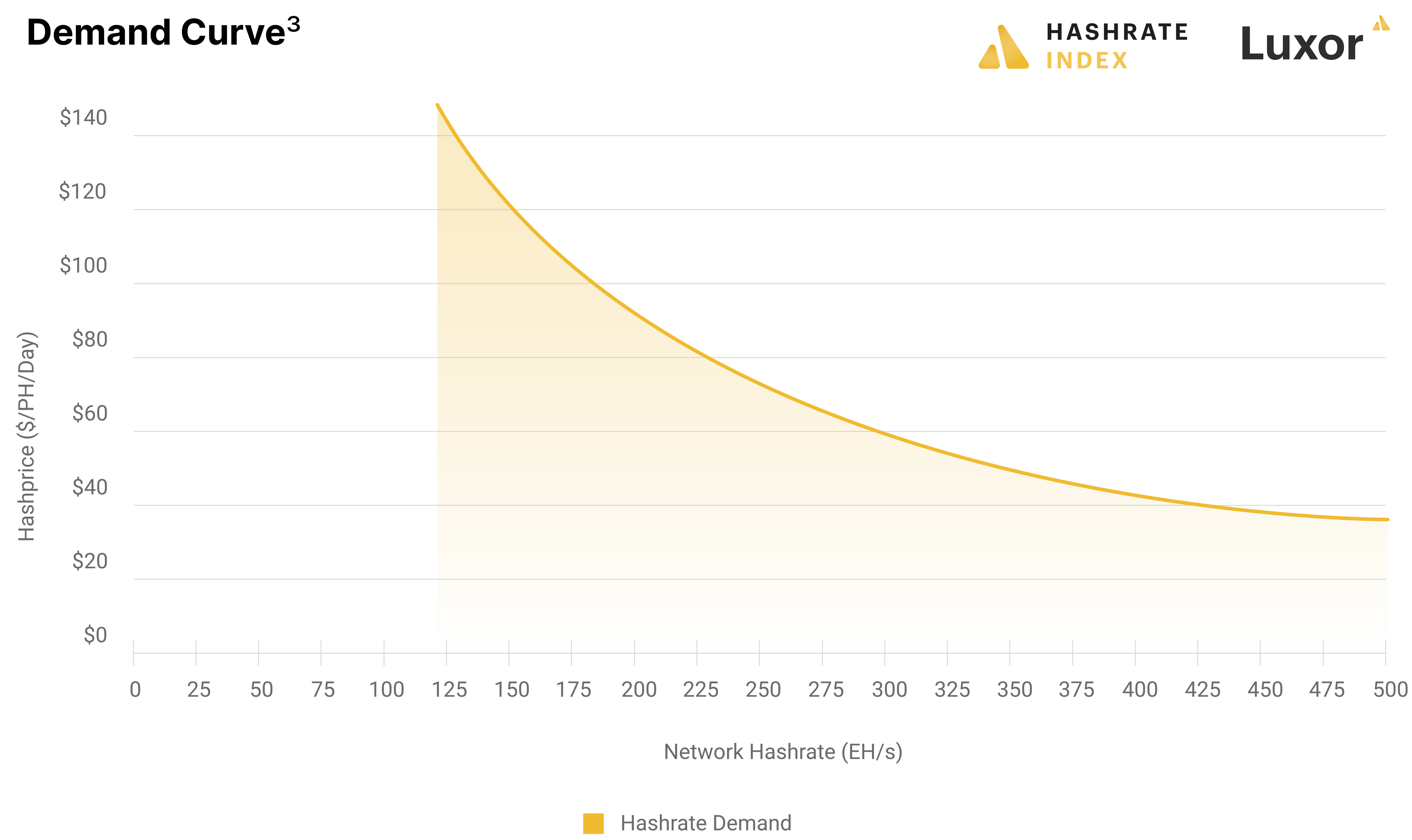
Holding block subsidy, transaction fees, and Bitcoin price constant, you can see in the equation above that there is a downward sloping relationship between hashprice and network difficulty.

Network difficulty is a quantitative measure of the probability of a miner or mining pool submitting a valid hash to the Bitcoin network's cryptographic hash function (i.e., SHA-256). Higher network difficulty indicates a lower probability of an ASIC submitting a valid hash, meaning it takes more hashrate to mine the same number of blocks.

Network difficulty is adjusted every 2,016 blocks (approximately every two weeks) to a level that targets an average block time of ten minutes. If network hashrate grows and blocks are found faster than 10 minutes on average, the network difficulty will increase. If network hashrate falls and blocks are found slower than 10 minutes on average, the network difficulty will decrease.

Therefore, network difficulty is just a proportional, indirect, and delayed measure of network hashrate. Given the proportional relationship between block times, network hashrate and difficulty, we can use the mining pool payout formula above to graph a downward sloping hashrate demand curve. It represents the hashprice miners can expect to earn for different levels of network hashrate, holding block subsidy, transaction fees, and bitcoin's price fixed.

Demand Curve[3]



[3] The demand curve shown assumes a $19,500 Bitcoin price, 6.25 BTC block subsidy, and 0.10 BTC transaction fees per block.

Constructing the Supply Curve: Physical Constraints and Mining Profitability

The supply curve for hashrate shows the relationship between hashprice and the amount of hashrate miners are willing to produce at different hashprice levels. Like in most cases, the hashrate supply curve has a slope that rises upward from left to right, since, as hashprice increases, miners are incentivized to produce more hashrate if they are profitable, and if it is possible to do so. Whether miners are profitable, and if it is possible for them to increase hashrate are key determinants of our supply curve.

If hashprice were high enough that any operating cost were profitable, we could assume that hashrate would primarily be a function of working ASICs in existence. Of course, there are other real-world constraints that would influence the maximum hashrate, such as the availability of power or infrastructure as we saw following the China mining ban. However, for simplicity, we have chosen to focus solely on the ASIC supply to estimate maximum hashrate capacity in this model.

Based on public filings, news releases, and other available research to determine ASIC manufacturers' historical and future production volumes, we estimate a maximum possible hashrate of approximately 345 EH/s at the end of 2022 and 475 EH/s at the end of 2023. We reached these figures by segmenting ASICs by efficiency tiers[4] (i.e., J/TH), estimating the total number of machines in each tier, and applying future production and scrap rate (i.e., machines that can no longer be used due to wear and tear) estimates.

Whether or not miners with different operational costs are profitable is the next piece of the supply curve. As hashprice declines, we expect miners with higher operating costs and lower-efficiency machines to stop supplying hashrate as they become unprofitable and turn off their machines. Conversely, as hashprice increases, we expect more miners to get plugged in to capture excess profits.

In this model, we represent profitability using gross mining margin. This factors in direct costs such as electricity, but excludes operational costs such as insurance, management salaries, depreciation, and other costs. This is an assumption to simplify the model.

We also realize there are situations where miners may continue to operate with negative gross mining margin. For example, adhering to long-term power contracts, a focus on revenue for valuation purposes, or circumventing capital controls among others. However, for this model we have chosen simplicity and focused on gross mining margin.

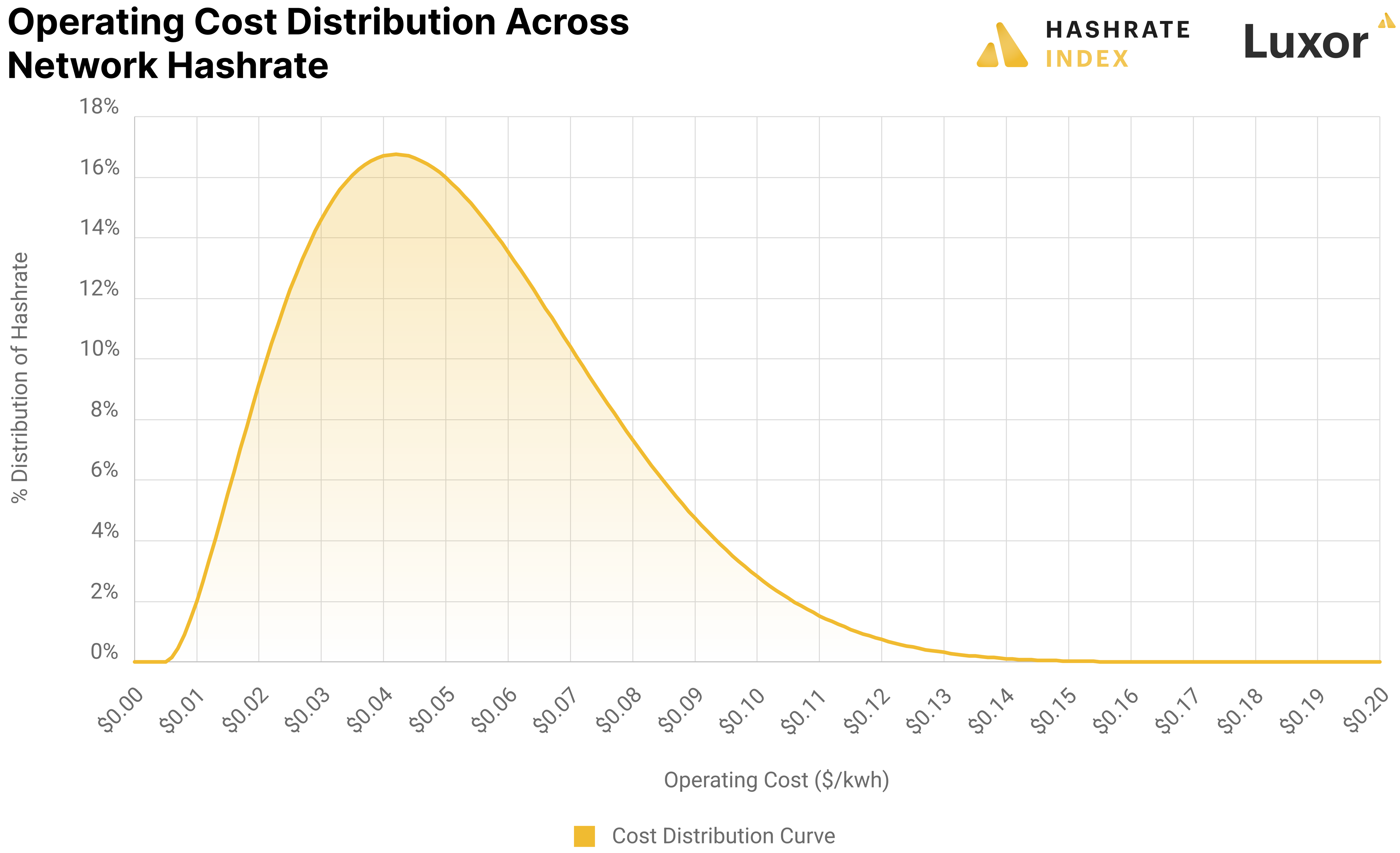
To estimate profitability distribution across network hashrate, we used public filings and insight from Luxor's internal database. First, we assigned each ASIC efficiency tier a set J/TH efficiency[5]. Second, we fit a right skewed distribution[6] of operating costs (expressed in $/kWh) across network hashrate, where the majority of hashrate has operating costs between $0.03 and $0.05 per kWh.

[4] ASIC efficiency tiers (i.e., J/TH) include old-gen (e.g., S9), mid-gen (e.g., S17), and new-gen (e.g., S19)

[5] J/TH efficiency: 90 for old-gen, 42 for mid-gen, and 28 for new-gen

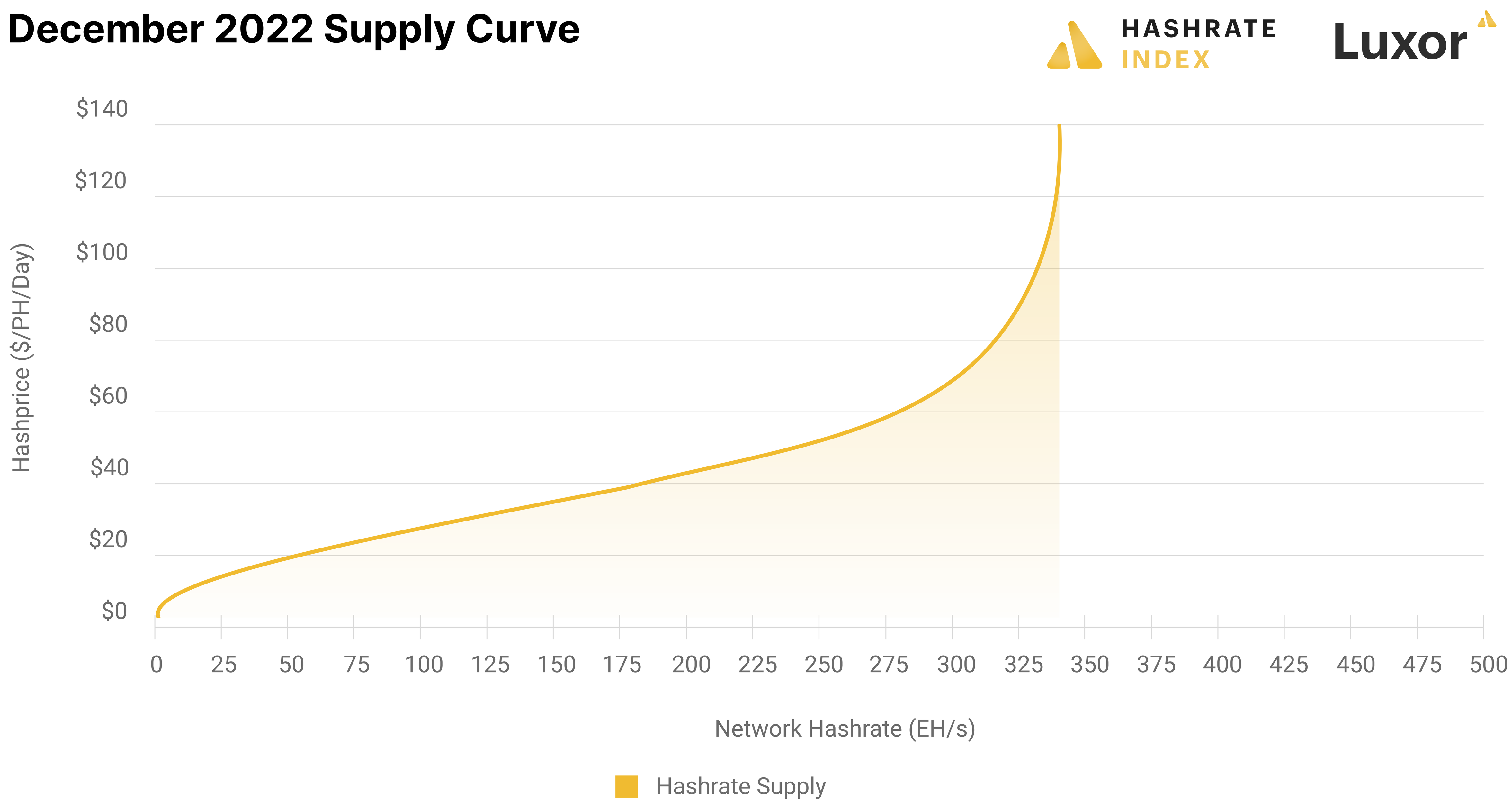
[6] Beta distribution with parameters values: alpha (2.75), beta (8.5); min (0.005); max (0.2).

Operating Cost Distribution Across Network Hashrate

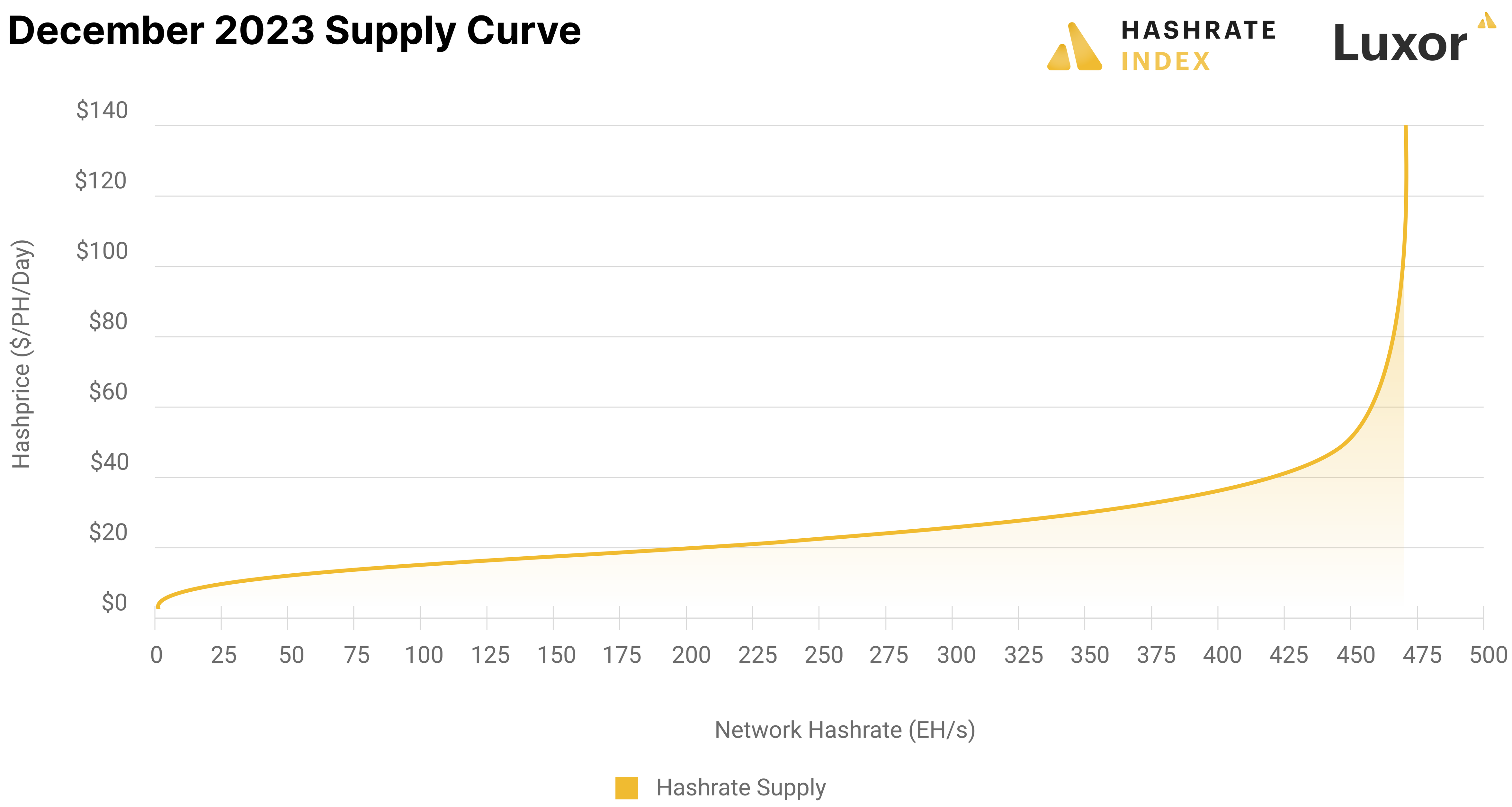


Then we used the efficiency tiers (i.e., J/TH) and the distribution of operating costs (i.e., chart above) to calculate break even hashprices across different operating profiles (i.e., efficiency tier and operating costs). Our supply curve was constructed by summing all profitable hashrate at each hashprice. The supply curves using the 2022 and 2023 year end ASIC supply estimates are both shown below.

December 2022 Supply Curve



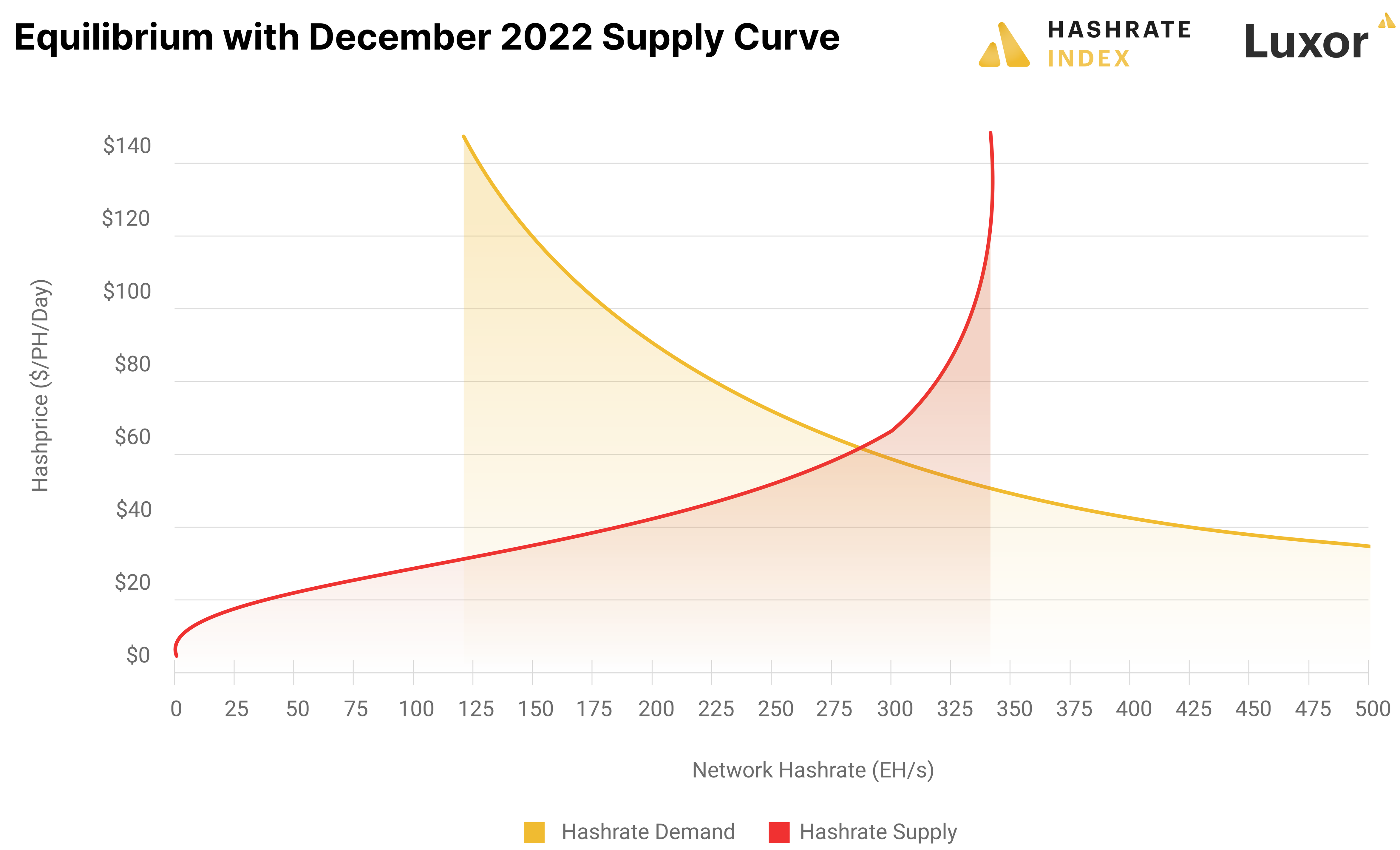
December 2023 Supply Curve

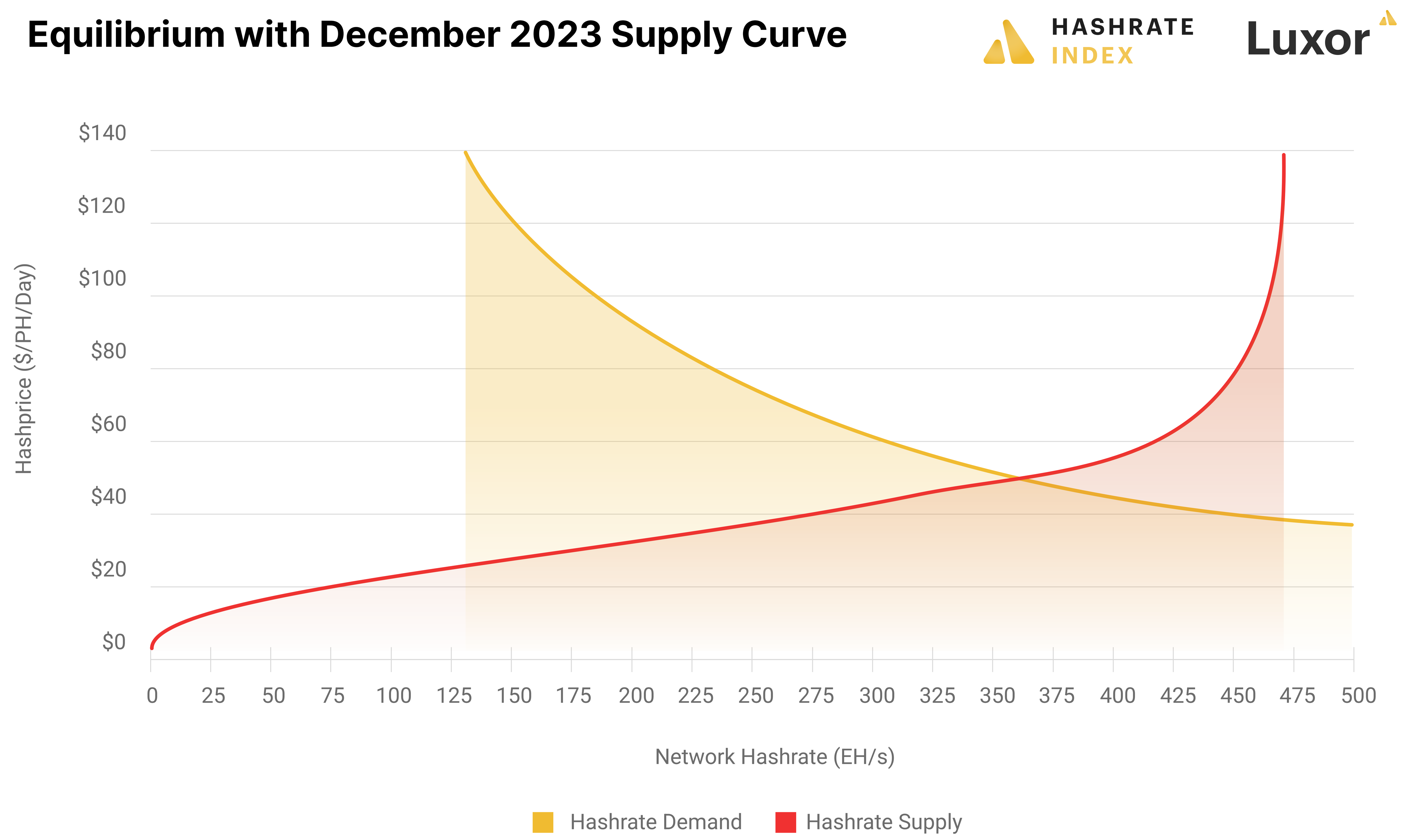


Analyzing Supply and Demand: Equilibrium and Caution

In economics, equilibrium is the state in which supply and demand are balanced. Absent changes in external forces[7], prices and quantities will tend toward equilibrium over time, and once reaching equilibrium, they will remain there. Instead of hashprice (i.e., price) determining hashrate (i.e., quantity) or vise versa, hashprice and hashrate are determined simultaneously by the intersection of supply and demand. Our model takes Bitcoin price, transaction fees, and block subsidy as inputs on the demand side; ASIC capacity and profitability on the supply side; and outputs an equilibrium hashrate and hashprice.

On our graph below, equilibrium is the point where the supply and demand curves intersect.





[7] In our model, external forces include Bitcoin price, transaction fees, block subsidy, ASIC supply, and the distribution of operating costs. These parameters determine our model's outputs – hashprice and hashrate.

The table below summarizes our model's equilibrium projections and associated assumptions.

	Dec-22	Dec-23
Model Outputs:		
Hashprice ($/PH/s/Day)	**$62**	**$51**
Network Hashrate (EH/s)	**286**	**360**
Network Difficulty	39.95T	50.29T
Demand Inputs:		
Bitcoin Price ($; CME Futures[8])	$19,490	$20,090
Block Subsidy (BTC)[9]	6.25	6.25
Transaction Fees (BTC)[10]	0.10	0.10
Supply Inputs:		
Supply Curve Est.	Dec-22	Dec-23

Now, the model's results must be interpreted with tremendous caution.

It is a mathematical representation of a system designed to further our understanding of how Bitcoin mining economics work and compare directional outcomes under various assumptions – not a completely accurate detailed mapping of the entire Bitcoin mining economy, or a forecast or prediction for the future. Different assumptions will produce different results. Further, in reality, external forces are always changing: Bitcoin prices, monetary policy, market conditions, and transaction fees to name a few, but the list goes on. The real world has more complexity than any model could ever hope to capture. Equilibrium is an abstract concept – in real life things are always changing.

Analyzing Supply and Demand: Is There a Hashprice Floor?

Our model suggests yes – but not where we originally hypothesized.

No matter how many miners come offline and how much network difficulty decreases, the corresponding increase in hashprice could be overcome by a potentially larger fall in the price of Bitcoin (i.e., a shift to the left of the demand curve). That is to say – the hashprice floor is zero.

Some logic that might support the hypothesis of a hashprice floor goes like this: "If the price of Bitcoin falls (the hashrate demand curve shifts inward), hashprice (price) declines because of Bitcoin's fall, and hashrate (quantity) because of unprofitable operations turning off machines, also decreases. The observed fall in hashrate (quantity) causes the supply of hashrate to fall (supply curve shifts inwards).

[8] CME Bitcoin Futures, quoted as at October 17, 2022 on CME's public website.
[9] As per the Bitcoin emission schedule.
[10] Used current transaction fees as the assumption going forward.

The fall in the supply of hashrate (supply curve shifts inwards) causes hashprice (price) to rise in response, possibly leading to a situation where the decrease in network difficulty more than offsets the fall in Bitcoin price.

But this logic suffers from some of the common mistakes people make when analyzing supply and demand. Namely, as pointed out by economist Russ Roberts in this blog post, confusing movements along the supply curve with a shift of the supply curve, assuming a shift in the demand curve causes a shift in the supply curve, and confusing a change in the equilibrium quantity with a shift in the supply curve.

However, our model indicates there are areas of what we call hashprice resistance. As Bitcoin price falls, and our demand curve moves to the left, there are regions where hashprice falls less per unit drop in the price of Bitcoin.

Assuming constant block subsidy and transaction fees, the tables below show our model's network hashrate and hashprice projections at each $2,000 Bitcoin price increment between $2,000 - $50,000 for the end of 2022 and 2023. The far right column in each table shows the corresponding change between hashprice in the row above vs. the current row. The areas with the smallest change in hashprice per $2,000 change in the price of Bitcoin are where the most hashprice resistance is, as we have defined the concept. Visually, the areas of most resistance are represented by the darkest shades of red in the charts below. Changes to hashprice are denoted as $/PH/day.

December 2022 Resistance Levels			
BTC Price	Hashrate	Hashprice	Hashprice Change
$50,000	339	$135	n.a.
$48,000	339	$130	$5
$46,000	338	$125	$5
$44,000	337	$119	$6
$42,000	336	$114	$5
$40,000	334	$109	$5
$38,000	333	$105	$5
$36,000	331	$99	$5
$34,000	329	$95	$5
$32,000	326	$90	$5
$30,000	323	$85	$5
$28,000	318	$81	$5
$26,000	313	$76	$5
$24,000	307	$72	$4
$22,000	298	$67	$4
$20,000	289	$63	$4
$18,000	277	$59	$4
$16,000	264	$55	$4
$14,000	248	$51	$4
$12,000	230	$48	$4
$10,000	209	$44	$4
$8,000	185	$40	$4
$6,000	155	$36	$4
$4,000	121	$30	$5
$2,000	76	$24	$6

December 2023 Resistance Levels			
BTC Price	Hashrate	Hashprice	Hashprice Change
$50,000	464	$99	n.a.
$48,000	462	$95	$4
$46,000	460	$91	$4
$44,000	458	$88	$4
$42,000	455	$84	$3
$40,000	452	$81	$4
$38,000	448	$78	$3
$36,000	443	$74	$3
$34,000	437	$71	$3
$32,000	430	$68	$3
$30,000	422	$65	$3
$28,000	412	$62	$3
$26,000	402	$59	$3
$24,000	389	$56	$3
$22,000	374	$54	$3
$20,000	358	$51	$3
$18,000	340	$48	$3
$16,000	321	$46	$3
$14,000	298	$43	$3
$12,000	274	$40	$3
$10,000	247	$37	$3
$8,000	215	$34	$3
$6,000	180	$30	$4
$4,000	137	$27	$4
$2,000	85	$21	$5

In 2022[11], our model indicates more hashprice resistance between a Bitcoin price of $6,000 - $24,000, with resistance strongest in the $12,000 - $18,000 range. While in 2023[12], our model indicates more hashprice resistance between $8,000 - $30,000, with resistance strongest between $14,000 - $24,000.

[11] Assuming constant block subsidy and transaction fees.
[12] Assuming constant block subsidy and transaction fees.

There are a couple important takeaways from the above charts.

First, hashprice resistance is marginal compared to the concept of a hashprice floor. Our model does not predict any situation where meaningful declines in Bitcoin's price can be totally offset by reductions in network difficulty. There are only minor variations in how much declines in network difficulty can offset declines in Bitcoin's price.

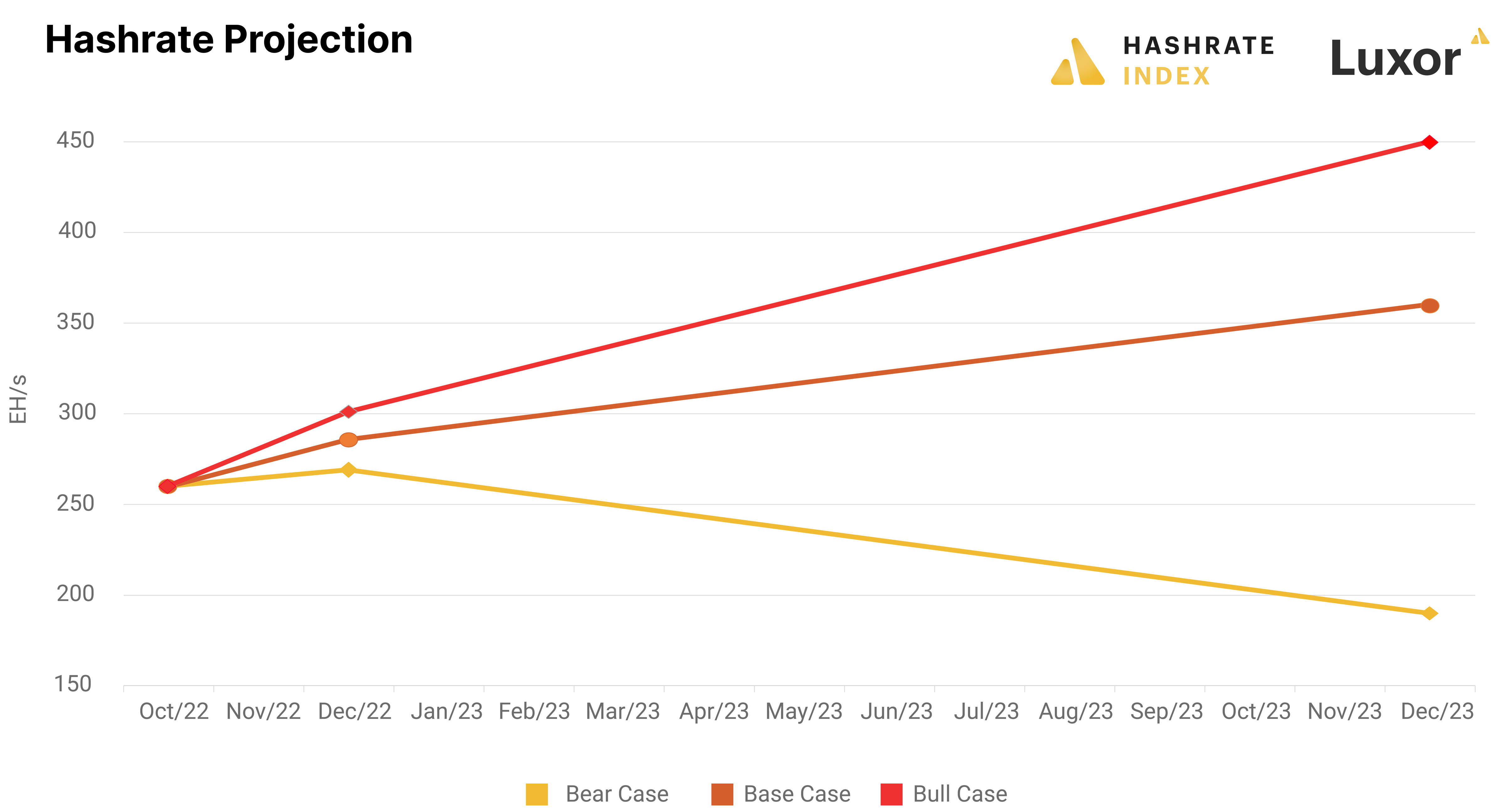
Second, there are potentially asymmetric returns available to miners if there are large increases in Bitcoin's price. While higher hashprice resistance can somewhat shield low-cost miners from declines in Bitcoin price on the downside, on the upside, lower hashprice resistance means increases in Bitcoin's price are relatively less offset by increases in network difficulty. This occurs because hashrate approaches maximum possible capacity and there are fewer and fewer miners who are able to take advantage of higher bitcoin prices by plugging in more machines. The increase in hashrate supply in 2023 hardens hashprice resistance across Bitcoin prices and makes these asymmetric returns only available at higher Bitcoin prices.

Analyzing Supply and Demand: Changes to Bitcoin Price Over Time

Our model can also be used to evaluate equilibrium dynamically over time and under different scenarios.

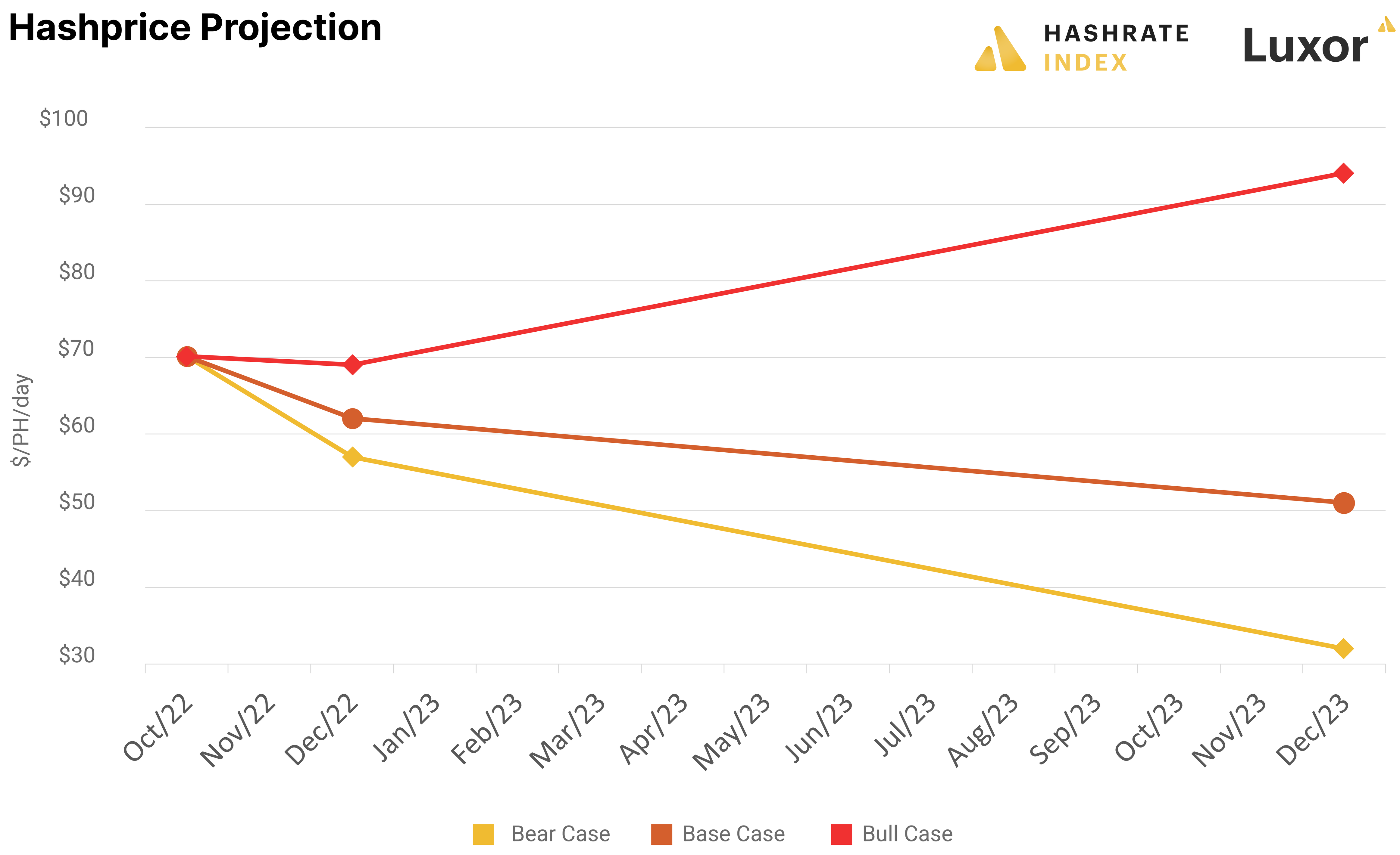
In the example below, we apply three Bitcoin price scenarios to evaluate how corresponding shifts in demand could impact equilibrium at the end of 2022 and 2023. The three Bitcoin price scenarios applied to the model were[13]: (i) a bull case with 7.5% monthly growth from the current price, (ii) a bear case with 7.5% monthly declines from the current price, and (iii) a base case using Bitcoin prices indicated by the CME Futures Curve[14].

Our results for hashrate and hashprice are shown in the charts below.



[13] Assuming constant block subsidy and transaction fees.

[14] CME Bitcoin Futures, quoted as at October 17, 2022 on CME's public website.



How Else Can Industry Participants Use Our Model?

First, it can be used to better understand how bitcoin mining economics work and compare directional outcomes under various assumptions. What happens at the halving? What happens if there is a sustained change in transaction fees or Bitcoin price? How would new ASIC technology increase the future production of hashrate? These questions and more can be analyzed with variations of this model.

Second, it can be used to gauge a miner's competitiveness. As with any competitive market, producers of hashrate with lower marginal costs will be better positioned to withstand bear markets. Where a miner is positioned on the supply curve will determine their competitiveness in Bitcoin mining.

Third, it could also be used as a starting framework for more refined analysis and accurate forecasting, and serve as an input for capital investment decisions. For example, miners could model future cash flows under various bitcoin price scenarios. This analysis could inform capital allocation decisions, such as determining whether new expansion projects or miner purchases provide acceptable returns. If miners are interested in taking on debt to finance certain capital investments, they'd also be able to ensure cash flows are sufficient to cover their expected debt costs - a particularly salient use case given the uptick in miner defaults in 2022.

Finally, and probably most importantly, the model could be used to assess financial risks and make hedging decisions. It is worth keeping in mind, there is no hashprice floor. Every miner is vulnerable to price declines at some point. Miners could use this model to explore the use of hedging instruments, like Luxor's Hashprice NDF, to build a more defensible business in a highly cyclical industry.