COINDESK RESEARCH NOTE

Gas Costs: Fueling the Blockchain Engine

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INTRODUCTION

The term "gas" has several meanings in the context of Ethereum.

It can refer to the cost or fee of sending a transaction on the network. It can also refer to a unit of measurement that estimates how much computational effort is required to execute a transaction or line of code. Gas can also encompass the entire price mechanism that calculates the cost of operations on Ethereum and incentivizes miners to execute them.

As a polysemic word, gas is most commonly used in the context of Ethereum as a synonym for transaction fees. However, its other lesser-known meanings are what explains how those fees work and the mechanisms that impact its value.

In this research note, we'll take a deeper look at the many definitions for Ethereum gas and explain how this understanding can be applied to interpreting the following metrics:

- gas cost.
- gas price.
- gas used.
- and gas limits.

We'll also touch on why some of these metrics evidence a growing need on Ethereum for increased scalability and transaction throughput.

This is not intended to be a mathematical paper. We will look at some simple formulas, but it is intended for those who are not statisticians. We aim to make the measurement and understanding of blockchain accounts accessible to everyone, as well as to underscore their importance to crypto assets and their potential role in investment portfolios.

This paper focuses on ether, the native cryptocurrency of the Ethereum network. Ether is most often used as the gateway asset to access decentralized applications (dapps) and Ethereum-based crypto assets such as ERC-20 tokens. When we use ether with lowercase, we are referring to the asset ETH, and when we use bitcoin with lowercase, we are referring to the asset BTC. Ethereum and Bitcoin with uppercase refer to the blockchain or the protocol. Dollars throughout are U.S. dollars (USD).

GAS COSTS

The cost of a transaction on Ethereum is determined by more than its size, that is how much ETH is being transferred. It is also evaluated by computation. This is because as a general purpose blockchain platform Ethereum is designed to execute much more than peer-to-peer transfers of value.

Ethereum has what is called a "Virtual Machine" able to crunch code of arbitrary complexity and length. Using the Ethereum Virtual Machine (EVM) incurs energy costs on miners, who are responsible for executing all code operations on the network. In order to price the cost of these wide-ranging operations, gas is used as a unit to measure how much computational energy each operation would require.

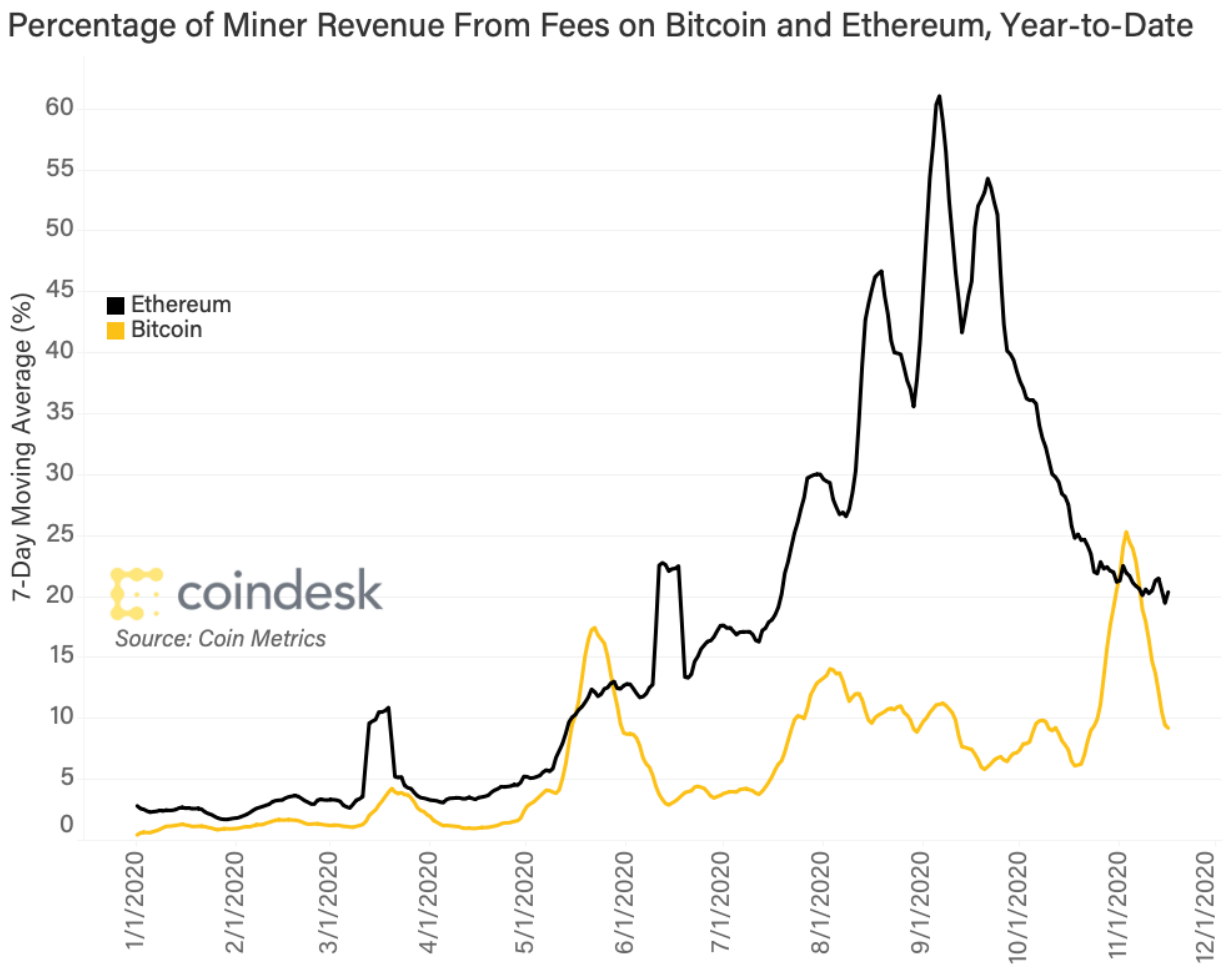
On Bitcoin, code operations are limited largely to transfers of BTC which do not vary widely in complexity and computation. On Ethereum, miners are rewarded for their work in processing not only transactions, but a whole host of other operations such as the destruction of a smart contract. (More information about smart contracts here.)

Destroying a smart contract costs 5,000 gas on Ethereum, which seems like a high number at first glance. But this amount of gas after conversion into ETH amounts to less than 0.001 ETH or $0.00 at time of writing. (We will discuss how to translate units of gas into ETH and USD in the next section of this report.)

Similar to how transaction fees are paid out to miners on Bitcoin, the gas cost of operations, including transactions, also gets collected by miners on Ethereum. On both networks, miners collect an additional reward subsidy for successfully appending new data to the blockchain. (More information about miner subsidies here.)

For the majority of 2020, Ethereum miners have been receiving a greater share of their revenue from fees as opposed to reward subsidies than Bitcoin miners.

The importance of fees to Ethereum miners vs. Bitcoin miners



The trends in the above chart suggest that fees have been playing a larger role in incentivizing the work of miners on Ethereum than on Bitcoin for most of the year. But in order for fees on Ethereum priced in gas to be of any real market value or worth, gas costs must be converted into ether, the native cryptocurrency of the network.

This is where the gas price comes in.

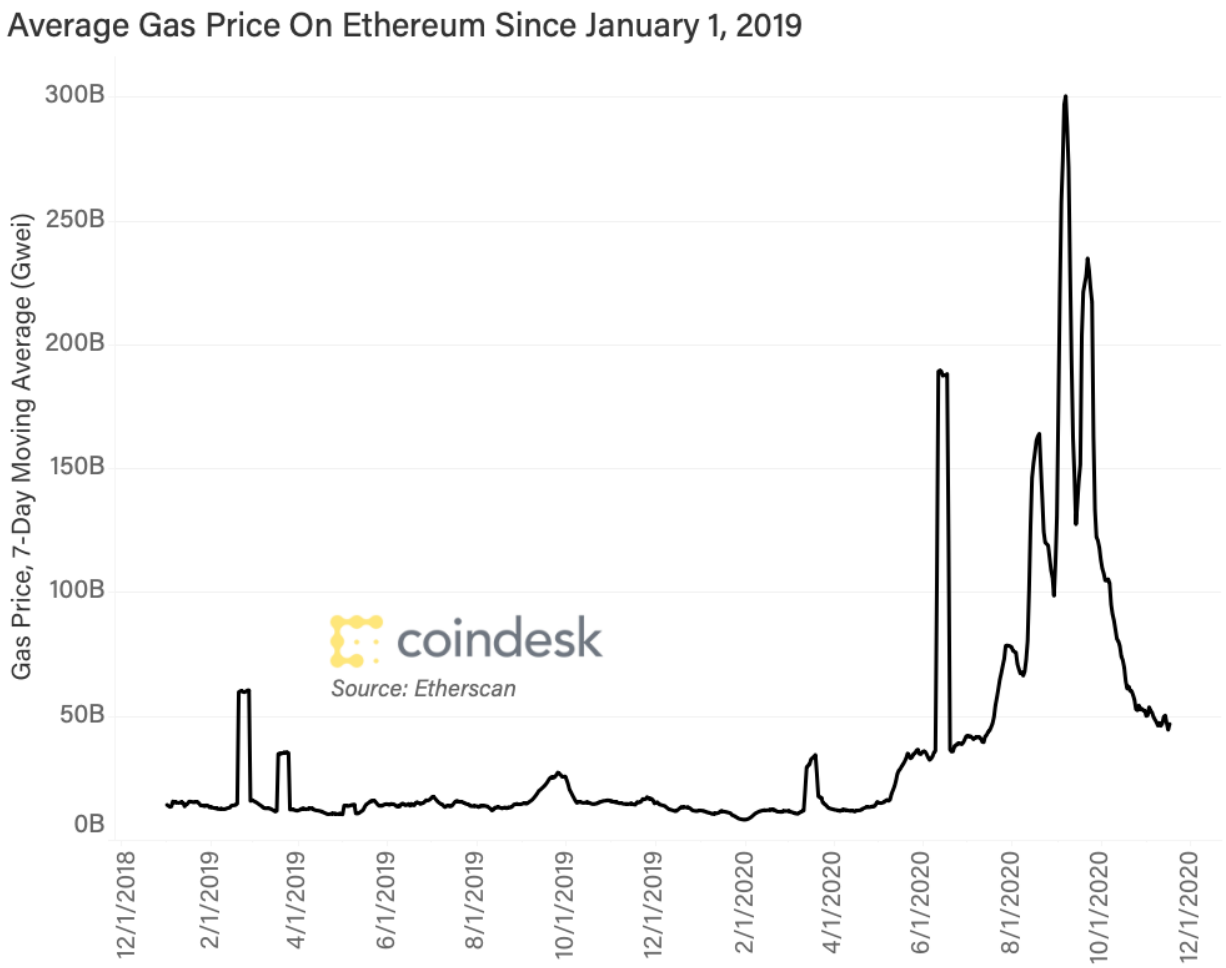
GAS PRICE

Gas costs, such as those mentioned above for transactions or account creation, are predetermined by the network and only alterable through a network-wide upgrade. The gas price, on the other hand, is the exchange rate between gas and ether that is set by the user. As such, gas costs for operations rarely change on Ethereum, while gas prices fluctuate frequently.

During times of network congestion, the average gas price tends to spike as users bid higher gas-to-ETH exchange rates for the processing of their transactions and code. Users who want to see their transactions and code executed faster on the network than others can incentivize miners by setting higher than average gas prices for their operations. This is similar to how users on Bitcoin can adjust the fees on their transfers of BTC depending on how quickly they need their transactions processed on the network.

Gas prices are usually denominated in units of gwei, which is one nano or one billionth of an ether. Tools like the ETH Gas Station help users estimate the cost for their operations and set a competitive exchange rate to see their operations executed in a timely manner.

Gas prices surge on Ethereum



Note: "B" denotes billions in the above chart.

The average gas price on Ethereum has increased significantly in 2020 as evidenced by the above chart. This suggests that transactions and other computations on Ethereum are becoming more expensive for the average user and dapp developer. High gas prices can pose a significant barrier against using Ethereum and its diverse dapp ecosystem.

In an interview with CoinDesk, Rune Christensen, founder of decentralized lending platform MakerDAO, shared his personal experience about what it was like to send transactions through Ethereum at the peak of the 2020 gas price runup. "During the peak of this hype, I was sending many transactions where I actually paid $100 [in fees] just to do one transaction and I was happy to do it because there were so many crazy opportunities to access at that moment," said Christensen, adding:

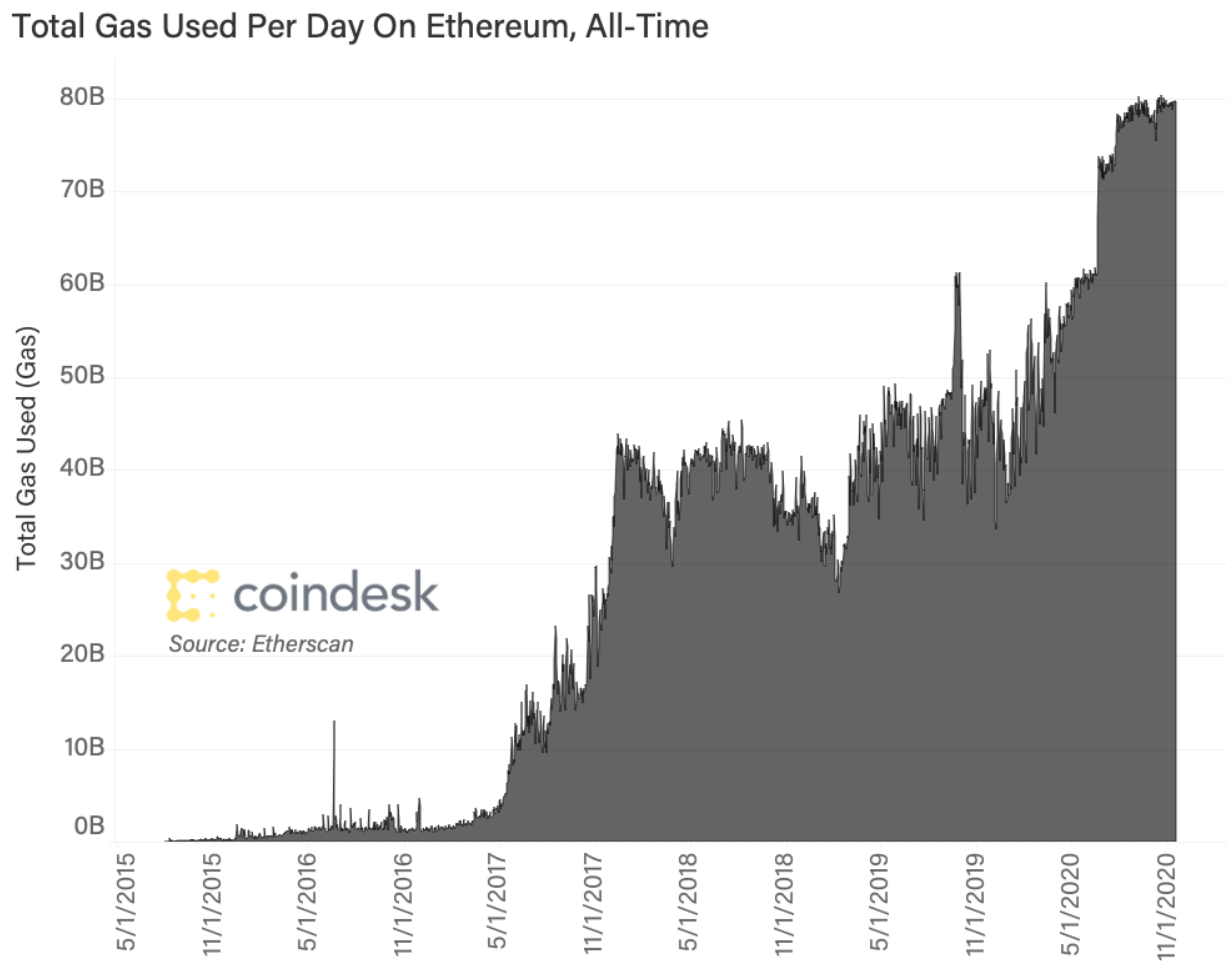
"Unfortunately, it means it's only the people with the most money and the most resources that get to access these opportunities because not everybody has enough capital that when they're doing a trade, it makes sense to send $100 in transaction fees."

In summary, fees on Ethereum are calculated by multiplying gas costs by a gas price. High fees are usually indicative of network congestion and times of increased user activity. In the next two sections of this report, we'll look at two more gas-related metrics that illustrate longer-term trends about network health.

GAS USED

Sharp spikes and drops in fees gives the impression that user activity on Ethereum is coming and going in short, ephemeral bursts. The reality as seen through the metric of daily gas used is that activity on the network has been mostly increasing throughout the five years since Ethereum's launch.

Gas used on Ethereum is steadily rising



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Daily gas used is the total gas spent in transactions and other operations by all users on Ethereum over the course of 24 hours. This metric removes gas prices, which are constantly in flux in the hands of users and dapp developers, and only sums the values for how much computational effort was expended by miners in a day.

Gas used is a measure of blockchain usage that accounts for all the activity generated on Ethereum not just by users but by dapps and smart contracts as well. Its growth over time

suggests that while the value users place on Ethereum network operations frequently oscillates, use of the network – be it by individuals, businesses, or dapps – is mainly rising.

GAS LIMITS

The final metric to be discussed in this report illustrates how rising usage of the Ethereum blockchain over the last five years has pushed network capacity to its very limits. As a safeguard against operations eating up more gas than a developer or a user intends, gas limits ensure no transaction exceeds a maximum gas cost. Like gas prices, gas limits are set by the user and are among the criteria that miners look at when prioritizing which operations on Ethereum to process. Low gas limits that do not sufficiently cover the expected gas cost of an operation are generally ignored by miners.

There are also block gas limits. These limits put a maximum on the total amount of gas that can be collected by a miner at one time. Bitcoin has an equivalent to block gas limits which is a maximum block size. Both of these metrics are intended to safeguard against the amount of data being processed by the network from becoming unmanageably large. Too much data runs the risk of slow block creation times and segments of the network falling out of sync when new blocks are appended to the blockchain.

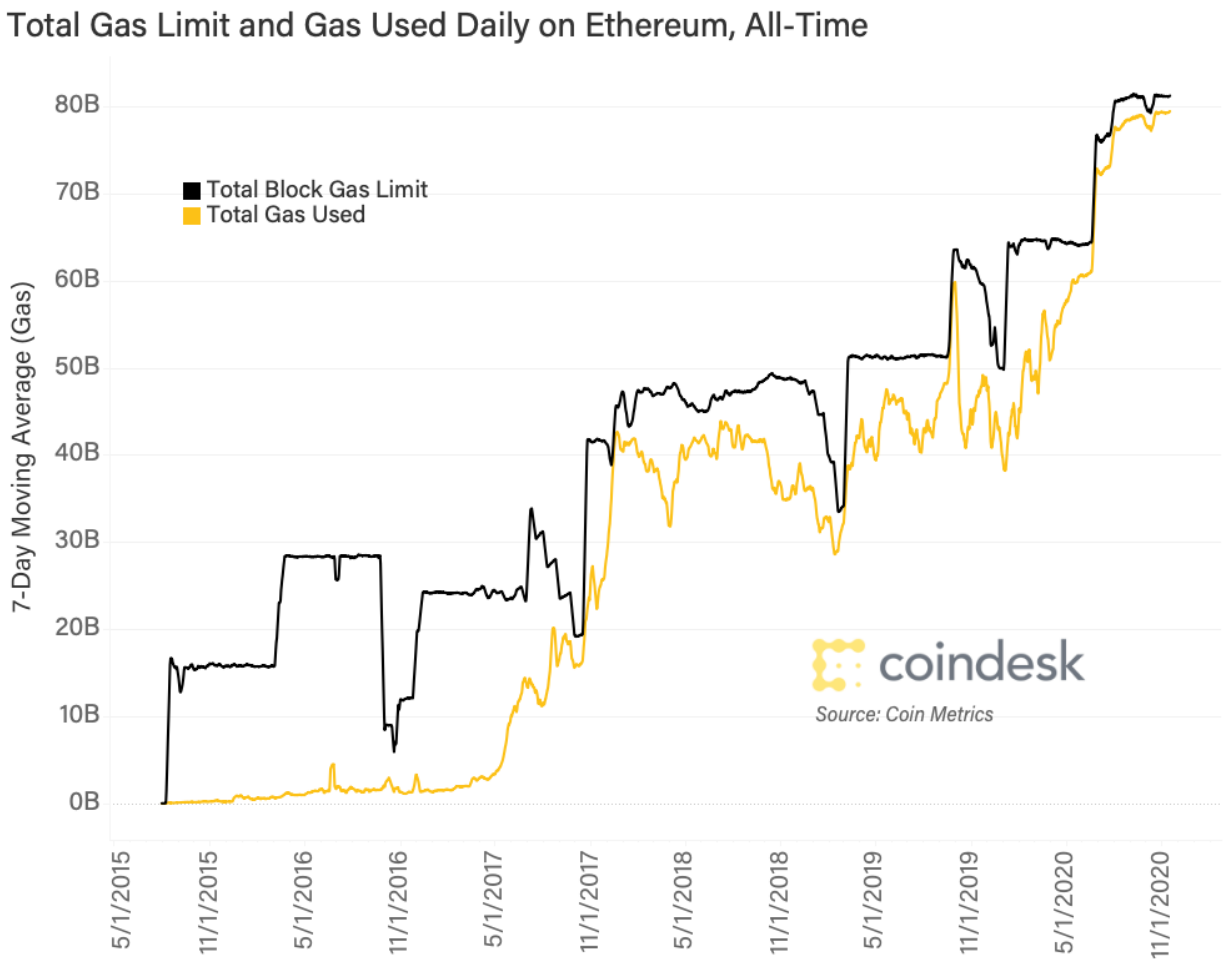
A summary of gas terminology

Term	Description
Gas	Unit for how much computation work is done.
Gas Price	How much you're willing to pay per gas for work (in gwei)
Tx Cost	Gas used * Gas Price
Gas Limit	Max gas you'll pay for a certain tx
Gas Block Limit	Max gas allowed in a block

Source: Eric Conner via Medium

Up until mid-2017, the sum of gas used in transactions rarely came close to hitting the sum of block gas limits in the same time period. A wide gap between daily gas used and the daily block gas limit indicates underutilization of the network's full computational capabilities and block space.

A summary of gas terminology



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However, from late-2017 onwards, Ethereum has regularly been hitting its maximum block gas limits, which has caused miners to incrementally increase these numbers in step with rising demand for the network's computational resources. As a function of the Ethereum protocol, miners can only adjust block gas limits by 0.0976% from the previous block's gas limit. When miners collectively agree a block gas limit is too low or too high, they can slowly work to edge that limit up or downwards with each consecutive block.

Significant increases to Ethereum's block gas limit have been made over the past three years but each raise has proven to be a short-lived solution that fails to relieve issues of network congestion and high fees over the long-term. The recent surge of popularity for DeFi apps and the dollar-pegged stablecoin USDT from late-2019 onwards has been the latest examples spotlighting the clear limitations of network capacity and the need for a scaling solution beyond incremental increases to block gas limit.

Ethereum 2.0 is one of those solutions, designed to radically transform the Ethereum blockchain and boost its computational abilities by a factor of 64. But the transition from Ethereum to Ethereum 2.0 is expected to take years to complete, which is why developers are also working on intermediate solutions. They include layer 2 protocols such as zkSync which are decentralized networks built on top of Ethereum. There are also innovations related to off-chain data aggregation, such as optimistic rollups, which bundle transactions and compress them.

CONCLUSION

Gas is the incentive mechanism that prices and orders operations on Ethereum. It is how miners are partially rewarded for their computational efforts in executing operations on the network and it is how the network measures, as well as limits, its computational load.

Gas is also a unit of account that, when multiplied with the metric of gas price, illustrates fluctuations in value for network resources. When average gas fees are surging, this indicates that users are willing to pay higher amounts to see their transactions and smart contract operations processed on Ethereum in a timely manner.

High gas fees and near-capacity blocks are an ongoing problem on the network that ebbs and flows depending on user activity and demand. While rising gas fees mean higher miner revenues in the short-term, they also limit growth by increasing the cost for potential new users and dapp developers.

The mechanism to incrementally increase network capacity on Ethereum is raising the block gas limit. It has proven insufficient to address the waves of popularity that certain dapps on the platform have been attracting from 2017 onwards. As such, there is a need for a long-term solution able to expand Ethereum's scalability and transaction throughput. Developers intend to deliver such a solution in Ethereum 2.0.

Because Ethereum 2.0 development is highly experimental and will take years to fully flesh out, the fee dynamics discussed in this research note are likely to retain their relevance for years to come. As a multifaceted word with many meanings, gas is critical for both users and investors to understand. It is the basis for several on-chain metrics such as gas cost, gas price and gas limits, each of which can be applied to measuring network health and activity over time.