NETWORK ASSESSMENT METHODOLOGY

1 PREAMBLE

CCRI **follows a standardized assessment process for Proof of Stake networks** (CCRI, 2022)[1], making reasonable assumptions if specific knowledge is not available outside in as described in the standard methodology. In this assessment of the Aptos network, CCRI is able to access details about network specifics provided by the Aptos Foundation, allowing an adjustment of the underlying data. For transparency, any deviations from the standardized approach in (CCRI, 2022)[1] are highlighted in blue.

2 STRUCUTRE OF THE MODEL

The model generates several key sustainability metrics of the Proof of Stake network, namely **electricity consumption** and **carbon footprint of the network**. For this, the model considers the nodes in the network and their individual power demands under different transaction throughput rates. The model contains following steps:

1. **We calculate the power of the entire network** (P_N), which we obtain by multiplying the number of all nodes (full nodes and validators alike) in the Aptos network (NC) by the power consumption of a representative node in the network (P_{BG}). To determine the power demand of the single best guess node, we leverage the measured metrics: we multiply the transactions per second (TPS) with the marginal power demand per one TPS (P_m), and add the node's base power demand (P_b), i.e., the power demand if the Aptos node software is executed at zero transaction throughput, to it:

$$P_N = P_{BG} * NC$$

$$P_{BG} = P_b + P_m * TPS$$

2. We derive the **electricity consumption of the Aptos network** (E_N) over a specific time period by multiplying the network's total power demand (P_N) by the considered time ($t[h]$):

$$E_N = P_N * t[h]$$

3. Third, we **calculate the carbon footprint of the Aptos network** (CF_N) by multiplying the network's electricity consumption over the regarding time period (E_N) by the carbon intensity factor of the network's grid (CI):

$$CF_N = E_N * CI$$

3 NETWORK ASSESSMENT

To generate the required parameters (namely P_b, P_m, CI, and NC), we follow the process as described in (CCRI, 2022)[1]. This standard methodology builds upon five steps to generate data on the electricity consumption and carbon footprint of a PoS system.

3.1 HARDWARE SELECTION

To come up with a representative hardware set of the network, we investigate Aptos' minimum hardware requirements, as these are an indicator of the hardware composition of the network. We use this information and additional hardware data from PassMark to select and obtain hardware that we use to measure a single node's electricity consumption. For measuring the Aptos network, we select devices 5 and 6 from our hardware (see Appendix for the devices' specifications). We rely on a binomial distribution, assuming that entities always adhere to the minimum requirements, but also might use more potent hardware.

3.2 HARDWARE MEASUREMENT

We measure the electricity consumption of a single node and provide upper and lower bounds for nodes in the Aptos network. We start by running the software required for participating in the network (*aptos-node-v1.16.3*) on all selected hardware devices and measure their electricity consumption while running the network and while idling. To be able to evaluate additional metrics, we capture further data points during the execution, such as CPU utilization, temperature, and processed blocks.

3.3 ELECTRICITY CONSUMPTION

We estimate the electricity consumption of the entire Aptos network. First, we collect information about the size of the network, i.e. the number of validators and full nodes, as the node count significantly influences the total amount of electricity consumed. Second, we use the binomial distribution between the single measured hardware. Third, we multiply the electricity consumption of the weighted nodes by the number of nodes in the network.

3.4 PERFORMANCE METRICS

We analyze additional data, such as transaction and block information, to develop further metrics to explore the energy efficiency of transaction throughput for each network. We take samples of the nodes' electricity consumption periodically and examine the number of transactions that the single nodes handled during the respective time periods. This allows us to describe the marginal influence of the number of transactions on the electricity consumption of a node in the Aptos network. As a result, we establish a model to estimate a best guess node's power demand based on the number of transactions. This enables us to model the electricity consumption of the Aptos network over time, as node count and transaction volume change.

[1] CCRI (2022). Determining the electricity consumption and carbon footprint of Proof-of-Stake networks. https://carbon-ratings.com/dl/whitepaper-pos-methods-2022

3.5 CARBON FOOTPRINT

We estimate the CO_2 emissions arising from the operation of the Aptos network. To do so, we use our data on network electricity consumption and multiply it by the carbon intensity of the network. We derive an appropriate carbon intensity of the network by leveraging the respective grid emission factors of the regions where nodes are located. We use location data from https://aptoscan.com/validators.

METHODOLOGY FOR SUSTAINABILITY INDICATORS UNDER MICA

1 PREAMBLE

The Markets in Crypto-Assets (MiCA) Regulation entered into force in June 2023. Crypto-asset issuers as well as service providers are required to disclose information on the principal adverse impacts on the climate and other environment-related adverse impacts of the consensus mechanism used to issue the respective crypto-asset. The European Securities and Markets Authority (ESMA), which has been mandated to develop draft regulatory standards related to sustainability disclosure, has proposed 6 mandatory climate and other environment-related indicators in their final report on the 2nd consultation package which was released on 4th July 2024. The six indicators cover the areas of energy and GHG emissions. Further optional indicators include, among others, waste production and natural resources.

Art 6 (1): Content and form of the crypto-asset white paper:

(j) information on the principal adverse impacts on the climate and other environment-related adverse impacts of the consensus mechanism used to issue the crypto-asset.

Market in Crypto-Assets Regulation (MiCA) for token issuers

Art 66 (5): Obligation for all crypto-asset service providers:

(j) Crypto-asset service providers shall make publicly available, in a prominent place on their website, information related to the principal adverse impacts on the climate and other environment-related adverse impacts of the consensus mechanism used to issue each crypto-asset in relation to which they provide services (…).

Market in Crypto-Assets Regulation (MiCA) for CASPs

CCRI has published a methodology document[3] to assess the 6 mandatory sustainability indicators as proposed by the ESMA in the final report on the second consultation package for any type of consensus mechanism, on which the following sections build on. For the **calculation of the indicators of the Aptos network,** we highlight all sources used in this document. Our **live data feeds might use different sources in the future**. For an up-to-date list of sources, **please refer to CCRI's API documentation**[4].

[3] https://carbon-ratings.com
[4] The documentation of CCRI's API can be found here: https://docs.api.carbon-ratings.com

2 INDICATOR OVERVIEW

The following table shows the six sustainability indicators as proposed by the ESMA in the final report of the second consultation package and their description.

Type	Adverse Sustainability Indicator	Metric
Energy	Energy consumption	Total amount of energy used for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions, expressed per calendar year Format: Amount in kilowatt-hours (kWh)
	Renewable energy consumption	Share of energy used generated from renewable sources, expressed as a percentage of the total amount of energy used per calendar year, for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions.
	Energy intensity	Average amount of energy used per validated transaction Format: Amount in kWh
GHG emissions	Scope 1 - Controlled	Scope 1 GHG emissions per calendar year for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions Format: Amount in tonnes (t) carbon dioxide equivalent (CO2e)
	Scope 2 – Purchased	Scope 2 GHG emissions, expressed in tCO2e per calendar year for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions (CO2e)
	GHG intensity	Average GHG emissions (scope 1 and scope 2) per validated transaction Format: Amount in kilogram (kg) CO2e

Source: ESMA, Final Report on the Consultation Package 2, Annex IV, Table 2

3 ENERGY-RELATED SUSTAINABILITY INDICATORS

The first three indicators are energy consumption related. Indicator 1 captures the total energy used for the validation of transactions and the maintenance of the integrity of the distributed ledger. Indicator 2 quantifies the renewable share, and Indicator 3 the per transaction energy usage.
We described the methodology for assessing the electricity consumption of the network in detail in A. NETWORK ASSESSMENT METHODOLOGY. The results from this methodology can directly be used for indicators 1, 2, and 3.

4 GHG EMISSION RELATED SUSTAINABILITY INDICATORS

To derive the GHG emissions for the validation of transactions and the maintenance of the integrity of the distributed, two components are required: (1) the energy consumption and (2) the emission intensity of the energy consumed. Both components have already been established and serves as a direct input for this section.

Indicator 4 – Scope 1 - Controlled

For the fourth indicator, ESMA asks for scope 1 GHG emissions for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions. However, special attention needs to be paid to the different scopes of the emissions.

The distinction of the emission in different scopes has been introduced by the GHG Protocol which provides guides for carbon accounting at the corporate level[5]. Scope 1 is defined as direct GHG emissions from sources that are owned or controlled by the company. As a crypto-asset is not a company, the distinction in emission scopes may seem somehow misleading in this context. We argue that a reasonable interpretation would be to think of the GHG emissions that are owned or controlled by the ones who validate transactions and maintain the integrity of the distributed ledger transactions (i.e., validators and full nodes). As the GHG emissions for the validation of transactions and the maintenance of the integrity of the distributed ledger occur during the production of the electricity that is consumed, the GHG emissions would only be owned or controlled by the validators and full nodes in case they are producing the electricity themselves. Given the amount of energy required for running an validator or full node, we would argue that it should be assumed that node operators are purchasing the electricity they use (which represents scope 2 – see indicator 5), unless there is clear evidence that a power plant is owned or controlled by the validator itself. The associated emissions would then be calculated by taking the electricity consumed by the owned or controlled power plant and multiplying it by the emission intensity of the respective plant (i.e., largely driven by the type of power plant, for example solar PV vs. wind. vs. gas). As the MiCA regulation foresees sustainability disclosures on the level of a crypto-asset and not on company-level, any information on potentially independently operated or controlled power plants must be taken from public reports from validators.

We are not aware of any validators or node operators running their own power plants for their operations; therefore we assume zero Scope 1 emissions.

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[5] https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf.

Indicator 5 – Scope 2 - Purchased

For the fifth indicator, ESMA asks for scope 2 GHG emissions for the validation of transactions and the maintenance of the integrity of the distributed ledger of transactions. Scope 2 is defined as indirect GHG emissions from emissions from the generation of acquired and consumed electricity[6]. In line with indicator 4, we would argue that a reasonable interpretation would be to think of the indirect GHG emissions of the acquired and consumed electricity of validators and full nodes. Similar to most other industries, we would argue that the majority of the validators purchase the electricity they consume rather than producing it themselves. The GHG Protocol presents two complementary methods to report scope 2 emissions:

- **Location-based method**: It reflects the average emissions intensity of grids on which energy consumption occurs (using mostly grid-average emission factor data). Therefore, the method requires the amount of electricity consumed at each location as well as the respective grid-average emission factors which are often published by state authorities (e.g., by the United States Environmental Protection Agency for U.S. states).
- **Market-based method**: It reflects emissions from electricity that companies have purposefully chosen (or their lack of choice). It derives emission factors from contractual instruments, which include any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims. As such, the market-based method does not only require information on the contractual instrument used (as well as associated credible claims) but also emission factors representing the untracked or unclaimed energy and emissions (termed the "residual mix") for the share of electricity for which there is no contractual information that meets the Scope 2 Quality Criteria.

The GHG Protocol requires both methods to be reported separately if one decides to start calculating scope 2 emissions with the market-based method (termed "dual reporting").

For the Aptos network, we use only the location-based method to report scope 2 emissions as detailed information on renewable energy claims is currently unavailable to calculate market-based scope 2 emissions and perform "dual reporting".

Indicator 6 – GHG intensity

For the sixth indicator, ESMA asks for the average GHG emissions (scope 1 and scope 2) per validated transaction. This metric has already been derived in A. NETWORK ASSESSMENT METHODOLOGY.

[6] https://ghgprotocol.org/sites/default/files/2023-03/Scope%202%20Guidance.pdf.