ICP SUSTAINABILITY REPORT 2023

Internet Computer Footprint

CARBON CROWD

DFINITY

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Executive Summary

Foreword

The Internet Computer Protocol (ICP) ecosystem has experienced impressive growth throughout 2023, both in terms of usage and network capacity. The Internet Computer Sustainability Report 2023 updates the 2022 report of the same title, providing a mechanism for comparing changes in gross emissions and network efficiency. Further, this report summarizes the progress on additional sustainability initiatives that have taken shape since the release of the 2022 report.

The Study

The network efficiency of the Internet Computer (IC) has increased markedly between 2022 and 2023. This can be explained by the larger load processed by the network which had budgeted reserve capacity. This trend confirms expectations that the IC will become increasingly efficient as it scales.

An increase in the count of nodes on the network has caused the gross emissions number to increase. Furthermore, the increased capacity in regions with worse emissions factors (e.g. South Africa), has caused the average emissions factor to rise. This demonstrates the continual trade-off between decentralisation and other priorities, such as sustainability.

While the average node power draw increased in 2023 the power consumption per transaction reduced significantly. Node power draw can be explained by a combination of increased network activity, the introduction of gen 2 nodes (which have an additional 4 NVMes), and improved availability of node power draw data. The reduced power consumption per transaction can be explained by increased activity on the network.

Several initiatives are underway to improve the ability to mitigate Scope 2 and Scope 3 emissions of the network. A working paper will be released later in Q1 of 2024 to outline the specific network objectives in these areas.

- The power consumption of a single transaction on the IC is 0.003 Wh/tx, down from 0.006 Wh/tx in 2022
- The direct electricity consumption of the IC is 1,248,694.2 kWh/year, up from 1,052,741.76 kWh/year in 2022
- The yearly scope 2 carbon footprint of the IC is ~389.0 tCo2e, up from ~275.8 tCo2e in 2022

Progress On 2022 Sustainability Proposals

In the 2022 sustainability report, five general proposals were made. Together, these represent decisive steps the ecosystem could take to improve network sustainability metrics. Of these proposals, two have been conclusively completed and two are set for completion early in 2024. Carbon Crowd is working closely with the DFINITY Foundation to outline updated objectives for network decarbonisation and expects to release a follow-up paper in Q1, 2024.

Proposals

- To develop real-time emissions tracking of the IC's energy consumption and associated carbon footprint.

Status: Completed

- Carbon Crowd Internet Computer Footprint Dashboard (ICF Dashboard)

Proposals

- For a dedicated resource to champion sustainability initiatives within the IC

Status: Completed

- Formal launch of the Proof of Green initiative at COP 28

Proposals

- To develop a fully decarbonised subnet on the Internet Computer

Status: In Progress

- Version 2.0 of the ICF Dashboard (Q1, 2024) will allow attribution of renewable energy consumption data from node operators already making use of renewable energy. Plans for supporting direct renewable energy purchases, and a data model compatible with future 24hr/carbon-free electricity are in development. This extends this proposal from a single decarbonised subnet to a fully decarbonised network.

Proposals

- to bring the network to carbon neutrality

Status: In Progress

- The ability for each node operator to have their emission directly offset will be a part of the V2.0 ICF Dashboard, expected release in Q1 2024

Proposals

- to tackle low-hanging-fruit to immediately reduce the carbon intensity of the IC network.

Status: Abandoned

- Not feasible to physically move nodes at this stage of network development. Plans to onboard and reward nodes based on environmental factors, alongside decentralisation metrics are now under consideration.

Introduction

In the contemporary digital landscape, the Internet Computer plays an important role in facilitating decentralized computation and enabling a host of new applications. This report aims to systematically assess the carbon footprint associated with the network, focusing on aspects such as node distribution, transactional volume, and its sustainable design principles.

A fundamental aspect of the analysis requires an understanding of the geographical distribution of nodes within the Internet Computer Network. By examining the dispersion and density of these nodes, we aim to uncover the localized environmental impact of data transmission and computational processes.

The inquiry also delves into the quantitative assessment of transactional and computational activities within the network. The volume of transactions and instructions executed is pivotal in understanding the environmental impact, as well as how these will evolve as the network grows.

The objective of the study is to present a comprehensive understanding of the environmental considerations intrinsic to the IC and highlight how these have evolved over the past 24 months. Through a measured and reflective approach, the hope is to contribute not only to the quantitative assessment of the IC's carbon footprint but also to the ongoing discourse on sustainable practices in digital technology.

The Study

This investigation centred on the examination of the Internet Computer (IC), necessitating a comprehensive understanding of its foundational infrastructure for a meaningful interpretation of results. The IC comprises 37 subnets, each typically consisting of a cluster of 13 nodes—physical servers distributed across various independent data centres worldwide. Smart contracts are confined to individual subnets, resulting in an uneven distribution across them and, consequently, varying workloads per subnet. Boundary nodes within the IC, responsible for routing incoming queries to subnets, are considered equivalent to worker nodes for this study's purposes.

The study focuses on scope 2 emissions. Notably, it confines its scope to the IC infrastructure, excluding the DFINITY foundation's additional infrastructure, such as the IC Dashboard and monitoring systems. Limitations primarily revolve around data clarity issues, prompting recommendations for subsequent reports to enhance data quality.

The methodology has undergone rigorous internal and external reviews, representing a continuous work in progress anticipated to adapt to evolving standards in the field. The methodology has been transformed into a real-time measurement process to predict the IC's emissions profile in real time.

Accurate measurement of inputs for this methodology is pivotal for producing credible outputs, demanding meticulous attention to data sources and continual enhancements in measurement techniques. Emission data relies on the regional grid mix as an approximation, incorporating sources from Electricity Maps, Watt-time, and the GHG Protocol (IEA, 2011) to yearly-submitted regional data (EPA, 2023).

The reported findings and comparisons emphasize scope 2 emissions, and briefly explores the comparative performance of similar blockchain and cloud solutions.

Measurement

We obtained single node measurements from a node on each of the subnets running in the IC, and from that derived an average for the power consumption of the nodes. This average power consumption is **0.255kw.**

We compiled data from the IC dashboard which reports in which region each node is running, this consists of **559 currently assigned nodes.**

Our emissions factor was initially calculated by averaging the emissions factor of each region that nodes were operating in **0.313 Kg/Kwh.**

We further refined this to account for the number of nodes running in each region coming to a weighted average of **0.311 Kg/Kwh**

Methodology

The IC maintains high levels of data availability, allowing for granular measurement of node regionality and corresponding emissions factors.

Nodes per region (Nr) remain available on the IC dashboard, and the regional emission factor (Ef) of all regions is either directly calculated from data providers (Watt time, Electricity Maps) or estimated (Climatiq, 2022). Per node electricity consumption (Ne) is calculated on an average of averages (updated from 2022 estimates) of nodes across each subnet, before extrapolation to the entire network.

Using the 'an1' (Flanders, Belgium) region as an example which has 64 (Nr) nodes with a regional emission factor of '~0.1' (Ef) kg/kWh. Assuming each node is drawing 0.255kW (Ne), then the total emissions/hour for this region is:

64 * 0.1 * 0.255 = 1.632 kg/kWh which can then be converted to tCo2e/year;
(1.632/1000) * 8760 = 14.30 tCo2e/year

Table 1 - Total Power Usage

Metric	2022	2023
Avg. hourly Energy Consumption per Node (kWh)	**0.232kwh**	**0.255kwh**
Total no. of nodes - assigned	**518**	**559**
Total no. of nodes - assigned & standby	**726**	**1318**
Annual consumption of active nodes (kWh)	**1,052,741.76**	**1,248,694.2**
Annual consumption of all nodes (kWh)	**1,475,464.32**	**2,944,148.4**

Table 2 - Emissions Factor And Carbon Footprint

Metric	2022	2023
Average emissions-factor (kg/kWh)	0.262	0.311
Total - active nodes (tCo2e/yr)	275.8*	389.0
Total - active + standby nodes (tCo2e/yr)	386.6*	916.0

*2022 figures have been updated using improved node power draw data that is now available, and differ from the 2022 Sustainability Report

The current industry standard for blockchain comparisons is energy usage per transaction. The observed transaction rate from the internet-computer dashboard was used, which was represented as 12,270 TX/s. Table 3 below represents the energy consumption of each transaction on the IC. Figure 4 provides a comparison (SSRN, 2023)

Table 3 - Observed Energy-Consumption Per Transaction On The IC

Active network (Wh/tx)	0.003227044281
Active + standby network (Wh/tx)	0.007608666123

Figure 4: A Comparison Of The Energy Consumption Per Transaction Between Blockchains (To Be Graphed)

Source	Watt Hour Per Tx (Reported)
Internet Computer	0.003
Hedera	0.003
Solana	0.517
Near	0.602
Avalanche	2.395
Algorand	3.411
Tezos	9.203
Ethereum	9.956
Polkadot	35.593
Cardano	41.27

Source: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4324137

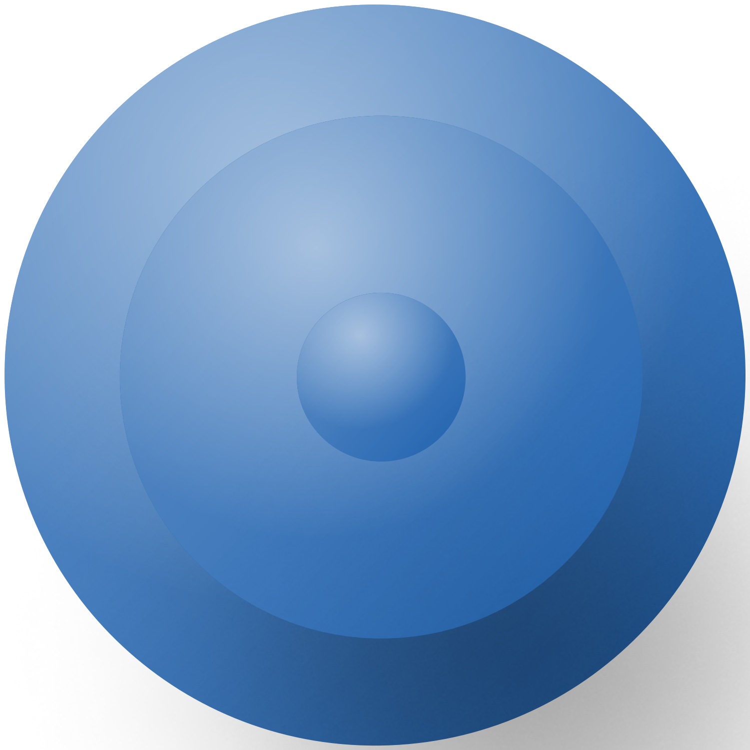
Conclusion

In 2023, the Internet Computer (IC) network underwent substantial transformations, evident in both the overall figures and the concurrent enhancement of network efficiency. The annual electricity consumption of the IC witnessed an increase from 1,052,741.76 kWh/year in 2022 to 1,248,694.2 kWh/year in 2023. This corresponded to a rise in annual Scope 2 emissions from approximately 275.34 tCo2e to about 475.5 tCo2e. Notably, the proportional increase in emissions exceeded that of electricity consumption due to the introduction of nodes in new regions characterized by higher carbon intensity grids. In this instance, the pursuit of decentralization had an adverse impact on sustainability.

Significantly, concurrent with the growth in emissions, the network exhibited an impressive 50% increase in efficiency. The power consumption for a single transaction on the IC halved from 0.006 Wh/tx in 2022 to 0.003 Wh/tx in 2023. Heightened network utilization and load processing allowed the IC to tap into the reserved capacity integrated into the system.

The trajectory toward enhanced network efficiency is expected to persist as network utilization continues to grow, with an anticipated acceleration in the coming years. This underscores the inherent sustainable design aspects of the IC network and emphasizes how these can evolve positively while maintaining a commitment to geographic decentralization.

Finally, numerous initiatives are currently underway to augment the network's capacity to address Scope 2 and Scope 3 emissions. A forthcoming working paper, scheduled for release in the first quarter, will delineate specific network objectives in these domains for the year 2024, further solidifying the IC's leadership as a green cloud network.



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