Carbon Footprinting Analysis Prepared For Gnosis Chain

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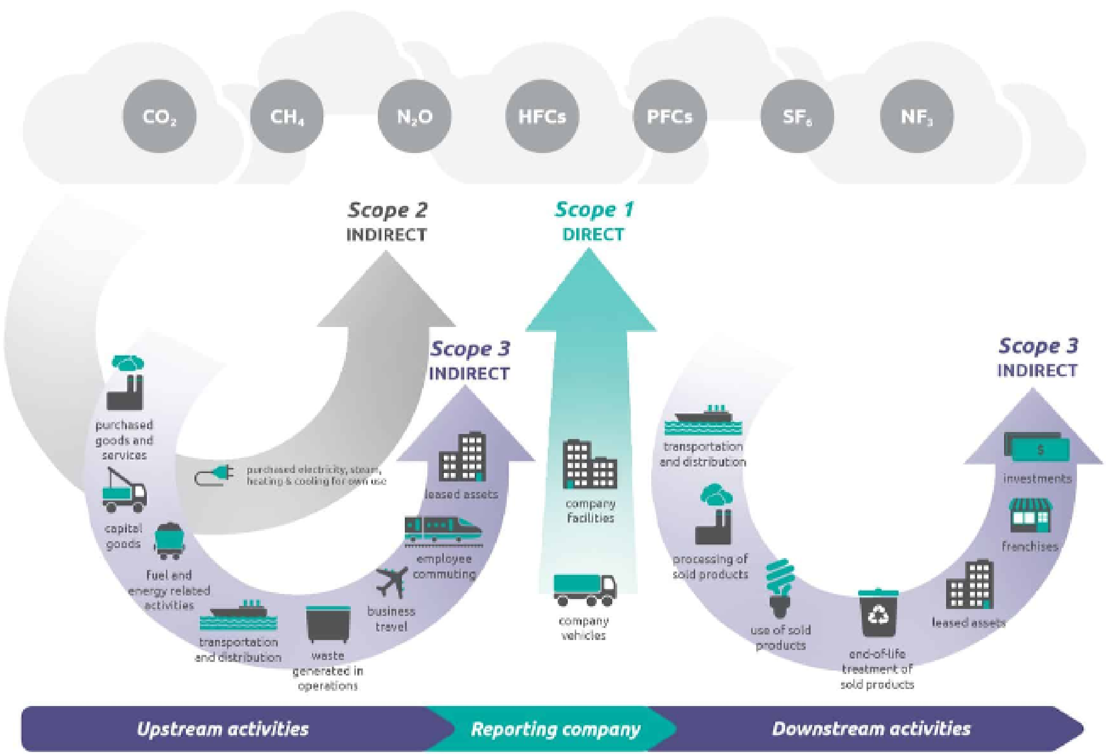
Contents

1. Background

Pursuant to xDAI's ambitions to understand their network's carbon emissions, Offsetra performed a corporate carbon footprinting (CCF) to analyze their blockchain network. Offsetra has included a cursory analysis of the business operations to determine their associated annual emissions. The analysis is measured in carbon dioxide equivalents (CO2e).

The report concludes with actionable steps to take as well as future recommendations for evaluating carbon impact and maintaining carbon neutrality.

The analysis of emissions in this report is divided according to the [Greenhouse Gas Protocol](), into direct (Scope 1) and indirect (Scope 2 and 3) emissions, presented below.



This is a novel area of analysis, and thus far the Greenhouse Gas Protocol does not have agreed upon guidance on how to approach the analysis of distributed networks such as xDAI. Hence, this report sets a precedent for future analysis of blockchain carbon footprinting.

2. Scoping

Scope 1 direct emissions originate from within the outlined system boundary of the company's own facilities, typically this would come from electricity consumption from the company's operations (e.g. manufacturing, and electrical Heating Ventilation and Air Conditioning). Scope 2 indirect emissions come from energy purchased by the company that has been converted offsite (i.e. fossil fuels) used to enable company operations such as heating and staff travel from the company fleet. Scope 3 indirect emissions come from external facilities that serve the reporting company, such as emissions from business travel, activities within the supply chain, or outsourced activity.

Offsetra's position on xDAI's network activity is to separate emissions associated with the physical infrastructure and energy consumption of the network. Network energy consumption, in our view, is directly related to the conditions of the network (uptime, throughput) and is paid for via staking rewards, and thus applicable under Scope 2. The physical infrastructure, on the other hand, is more variable (in the sense that only minimum conditions must be met) and is ultimately paid for by third parties. Hence, we consider these emissions under Scope 3.

The temporal scope for this analysis was 1 year (October 2020 - October 2021), as per the data submitted to Offsetra by xDAI.

The below table summarises the areas of emissions covered in this report, against their respective Scope. Key activities that would make up a full Corporate Carbon Footprint (CCF) such as employee travel and purchased goods & services have not been included in the analysis.

Scope	Data Item
1	n/a
2	Remote employee emissions
	xDAI - Energy Consumption
3	xDAI - Physical Infrastructure

3. Explanation of Emissions Calculation

The emission factors used in this report are from internationally recognized sources, suitable for best practice emissions analysis. A full list of sources is included in the attached Spreadsheet. Raw data tables are also viewable in the attached Spreadsheet. The subsections below briefly introduce the approach to derive the carbon impact for each activity from xDAI and the network.

3.1 Energy Consumption (remote employee emissions)

Classically, meter readings (for gas and electricity) or receipts for orders such as heating oil or coolants provide the data required to define the carbon footprint of energy consumption. In lieu of meter reading data, Offsetra utilized existing research exploring the energy consumption that remote work is responsible for, across both electricity and natural gas usage, to determine the emissions of employees (1). This research included some delineation across geographies and utilized 2021 emissions factors for both natural gas and electricity generation. Offsetra has assumed 220 days worked per year as part of a full time contract.

The analysis does not consider employee travel, or goods/services that may have been purchased for employees.

3.2 Staking Nodes

The hardware required to run staking nodes are the cause of the network's power consumption (Scope 2), and constitute the physical infrastructure of the xDAI network (Scope 3). Offsetra modelled Node system requirements after an AMD EPYC and HPE ProLiant server (both configured with 8 processing cores). The AMD EPYC is considered at the lower end of servers used based on the data shared by xDAI, the HPE ProLiant server characterises the top end power requirements to secure the network. Both the low and high power consumption scenarios were utilized to create a baseline estimate for the minimum energy consumption which can then be used to define the total carbon footprint of the network's electrical demand.

A realistic energy consumption estimate for a validator node needs to factor in both the minimum hardware requirements as well as the utilisation of the hardware. The methodological approach to identify the power consumption of the network is to arrive at an energy consumption per transaction metric (*ctx*). To achieve this, the number of transactions per unit of time needs to be considered (*l*), as well as the power consumed by a validator node (*p*, measured in W) and number of validators (*nval*). All variables are considered constant for the temporal scope of 1 year. Hence,

$$c_{tx} = \frac{n_{val} \times p}{l}$$

Consensus related energy demand in PoS is constant (i.e. it occurs irrespective of system load), Offsetra has however applied a load factor of 0.5 for the servers considered, given it assumed that even locally owned servers will be running VMs to conduct other activities.

The *ctx* value is then multiplied against the emissions factors of the power system based on the locations where xDAI network activity takes place to derive the carbon footprint of electrical demand. The distributed nature of the network means that the carbon impact of a given xDAI node operator is variable depending on the country where activity takes place. There is limited data on the geographic locations where node operators are based. However, it is known that there are 2 in the US, 1 in the UK, 1 in Germany, and 1 in Romania. In light of this, an approach has been taken where the emissions factors for validators in known locations have been given a higher weighting in the analysis than other locations where Proof of Stake node operators commonly have a presence (e.g. Europe, the US and Asia). Offsetra has extrapolated the best available data from a range of sources to develop up-to-date emissions factors for the purpose of this analysis in lieu of any single database for emissions factors being available.

In addition to the raw power demand of the xDAI network, physical hardware is required locally, whether or not the xDAI nodes are being run virtually or not. Hence, for a given period of time, 19 pieces of physical hardware are locally required and a Product Carbon Footprint (PCF) should be allocated to the xDAI network's Scope 3 emissions to cover the carbon impact of this hardware. Hewlett Packard have published transparent data for the PCF of PCs and servers, and a median value for desktop PCs is used to characterise the assumed PCF for 1 year of operation. The PCF internalises Scope 1, 2 and 3 emissions required to source materials, manufacture and distribute the hardware to a consumer.

The Product Carbon Footprint of the cloud-based hardware (i.e. servers) used to secure the xDAI network is significant; for example the HPE Pro Liant's entire PCF is 6.27 tCO2e across its entire lifecycle. However, given that some staking nodes run on the cloud and these emissions should be captured within the CPF of the corporations or entities running the servers, it is not considered reasonable to allocate the PCF of these servers to the xDAI network.

3.4 Standards of Calculation

The following five principles are a central element of the Greenhouse Gas Protocol on which every step of greenhouse gas accounting is based:

- Relevance: The GHG collection must adequately record and present all relevant emissions of a company.

- Completeness: The calculation must capture all emitted greenhouse gases. If certain emission sources are not recorded, this must be clearly noted and justified in detail.

- Consistency: The calculation must be based on uniform methods. Any change in the data basis, calculation limits and emission factors must be reported.

- Transparency: Based on an accurate audit scheme, all collected data must be presented in a clear and coherent manner. The assumptions, emission factors and methods used must be documented.

- Accuracy: It must be ensured that the quantification of greenhouse gases is neither systematic nor below actual emissions and that uncertainties are minimized as much as possible.

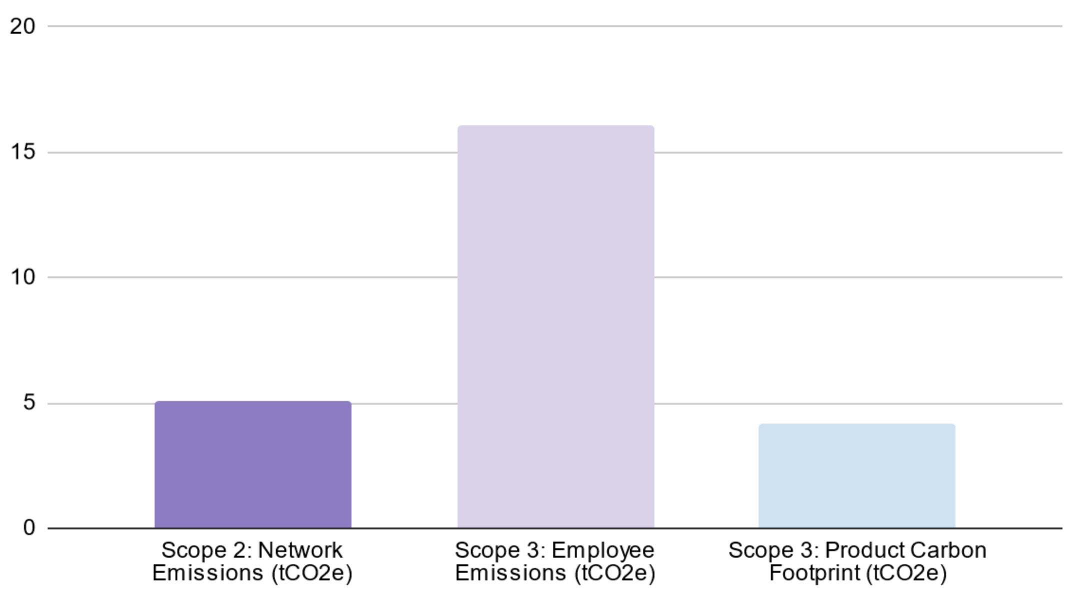
4. Results

This section of the report details the results of the analysis for the direct and indirect emissions of xDAI, using the Scope 1, 2 and 3 definitions. Raw results tables are available in the attached spreadsheet. Given that all employees are remote, and the xDAI network itself has no centralised location where commercial activities take place, there are no Scope 1 emissions allocated to the xDAI network.

The graphic below summarises the Scope 2 and 3 analysis of the xDAI network. This covers emissions associated with power consumption required to secure the network from node operators, the carbon emissions from the physical hardware required to run operating systems and servers to participate in network activity, and the emissions from employees who work full time on maintaining and undertaking associated activities on behalf of the xDAI network.

The carbon emissions from the electrical demand of the xDAI network is 5.08 tCO_2e. The emissions from the physical hardware required locally to participate within the network is 4.19 tCO_2e. The total carbon footprint required to secure the network is 9.28 tCO_2e. The emissions from the full-time employees that are responsible for the xDAI networks corporate operations is 16.07 tCO_2e. Hence the total carbon impact of xDAI's operations is 25.35 tCO_2e.

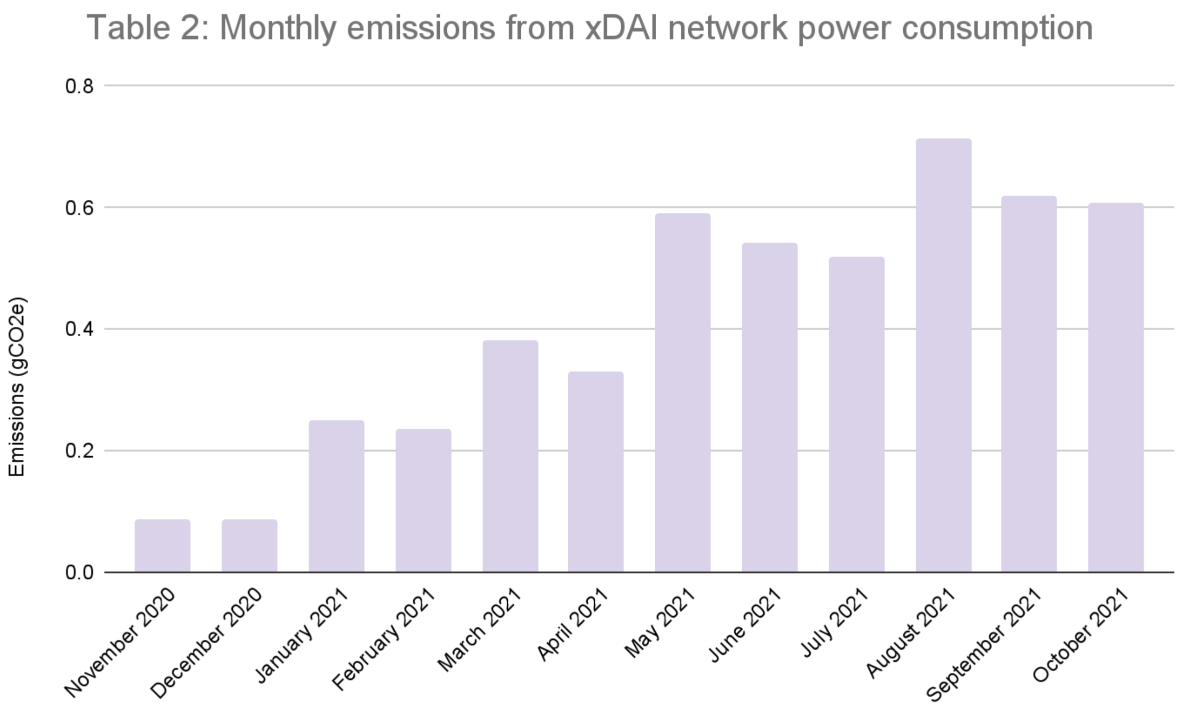
Table 1: xDAI Carbon Emissions Summary



Overleaf, the results from the respective areas of analysis are broken down.

4.1 Scope 2

The Scope 2 emissions of 5.08 tCO_2e relate only to the electricity consumed by staking nodes. No further analysis was required for Scope 2 emissions because there is no centralised office location owned by xDAI that would otherwise have a carbon impact. Hence, this total carbon footprint is derived from the known operating conditions of the network, and this gives the network an emissions factor of 0.14 gCO_2e/txn. This can be allocated across the network's activity for a given time period, graphed below for each month of the study period based on known transaction data.



Given the network's throughput over the past year (2.9 txn/s), the carbon emissions have been lower than what would have occurred if the network had operated at its theoretical maximum capacity (70txn/s). Had the network been operating at full throughput throughout the entire year, the carbon footprint of the network would have been 7.26 tCO_2e if the same conditions were present (i.e. 19 validators operating with the same hardware assumed in this analysis). This is a difference of 2.18 tCO_2e between the actual emissions of the network, and the theoretical maximum. Note that although the carbon footprint would be higher at the theoretical maximum, the efficiency of the network would also be greater meaning the emissions factor achieved could be as low as 0.003 gCO_2e/txn.

The aggregated grid emissions factor used to derive the carbon impact of power consumption of the network is 361.5 gCO_2e/kWh.

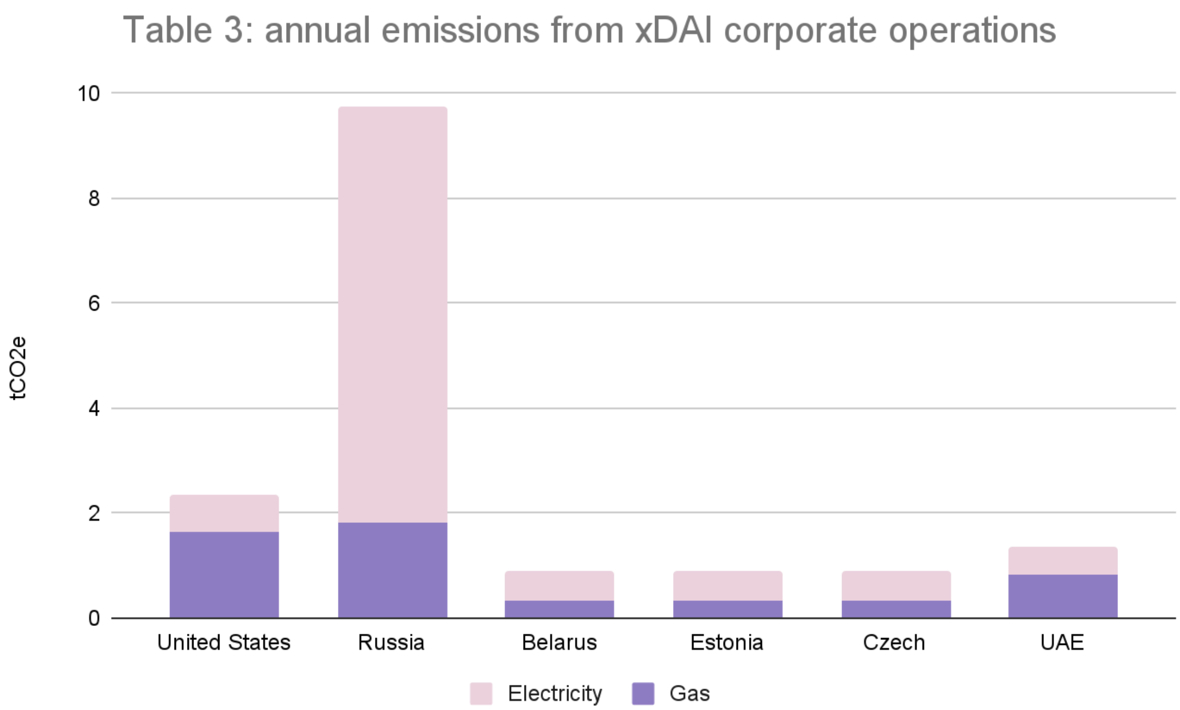
4.2 Scope 3

The majority of carbon emissions (>75%) that xDAI is responsible for can be categorized as Scope 3 emissions. These emissions come from the carbon associated with the locally-owned hardware required to run the network, as well as emissions from the corporate element of the xDAI network.

The analysis has assumed that the average PCF (full life-cycle) for the hardware that is required locally to run the network is 0.6625 tCO2e, and that the minimum lifetime of these assets is 3 years. Hence, for the one year period this analysis covers, it is calculated that the carbon emissions associated with locally owned hardware to secure the network is 0.22 tCO2e. Summing this to cover the 19 validators that are required to secure the network at a given time gives the total PCF associated with the xDAI network as 4.19 tCO2e.

To contextualise the total impact from network activity against other corporate activities, a cursory analysis of employee's emissions from home working has been included which includes the gas and power consumption required for a home office over an assumed working year of 220 days (note this analysis excludes corporate travel and goods/services purchased to enable home working activity). The total emissions allocated to xDAI's home working requirements is 16.07 tCO2e. Hence, the emissions associated with this activity are significantly greater than both the power consumption of the network and the PCF associated with the network.

Given the distributed nature of xDAI's workforce, there is notable variance in the emissions associated with this activity based on the location of the employee. There are no data gaps around where employees are based and the carbon emissions associated with their activity can be presented as presented in the graph below.



4.3 Summary of Network Emissions Results

The power consumption of a Proof of Stake network has typically been used by analysts to determine the carbon footprint of various networks. However, as this piece of work has been undertaken inline with the Greenhouse Gas Protocol methodology, the analysis of the network's Product Carbon Footprint from the physical hardware requirements has been included to align with best practice.

Hence, the network's total carbon footprint derived from power consumption summed with the physical hardware CPF is 9.28 tCO2e for the period October 2020 - October 2021. This is equivalent to an emissions factor of 0.14 gCO2e/txn.

1. xDA emissions factor from network load	**0.078 gCO2e/txn**
2. xDAI emissions factor (total)	**0.143 gCO2e/txn**

When comparing xDAI's carbon performance with other analyses of the Proof of Stake and Proof of Work blockchains, the xDAI emissions from the network load (1) should be used. For a more accurate and comprehensive discussion of xDAI's total carbon impact from network activity, the total emissions factor (2) should be used.

5. Summary and Recommendations

The results of this work indicate that the carbon impact of the xDAI network is significantly lower than many other blockchains running on Proof of Stake, and orders of magnitude lower than Proof of Work blockchains.

The first steps of the analysis undertaken by Offsetra in this report is the same methodology used by the University College London (UCL) in their October 2021 Discussion Paper "Energy Footprint of Blockchain Consensus Mechanisms Beyond Proof-of-Work" (2). The analysis deployed in this Report diverges from the UCL analysis when at the point where Offsetra applies a load factor to the calculations to more fairly attribute the actual CPU usage to xDAI. The UCL paper does not consider the emissions impact of the network. However, the UCL analysis can serve as a useful baseline to compare the general efficiency (in terms of electrical consumption) of xDAI compared with a number of other networks. As demonstrated in the table below, xDAI performs well from an efficiency perspective compared to all the other blockchains listed (as well as against VisaNet). Hedera, the only blockchain which performs better here, has fewer node operators than xDAI and a high transaction per second throughput which leads to highly efficient network conditions.

Platform	Per transaction (kWh/txn) upper	Per transaction (kWh/txn) lower
Algorand	0.00534	0.00017
Cardano	0.37854	0.01239
Polkadot	0.11556	0.00378
Tezos	0.01096	0.00036
xDAI	0.00029	0.00014
Hedera	0.00004	0.00002
Bitcoin	3691.40700	360.39300
Ethereum 2.0	0.55713	0.00009

VisaNet	0.00358

The low carbon impact of the xDAI network is also attributed to the fact that there are relatively few validator nodes required to secure the network at a given time (19). In addition, the xDAI network is also running at a relatively low capacity (4%) compared to its theoretical maximum. In the case that the xDAI network increased its throughput, then the total emissions of the network would increase, however the per transaction carbon impact of the network would decrease as the impact would be attributed across more transactions.

Despite the relatively low emissions attributed to xDAI for the past 12 months, the network has grown significantly during this time. In the case that the network's current operating parameters changed and the number of live node operators increased from 19 to add additional capacity to the network, then the carbon emissions from the network would rise more quickly. It is therefore recommended that the xDAI network continue to undertake this analysis on an annual basis to monitor the carbon impact and efficiency of the network as it grows.

The cursory analysis of the employee emissions indicates that the emissions from xDAI's network activity is ultimately smaller than other areas of economic activity. The carbon efficiency of Proof of Stake networks is acknowledged as a key benefit for the transition away from Proof of Work. However, this Report does not begin to consider the financial and ethical considerations around the carbon impact of blockchains in comparison to more conventional aspects of economic activity.

5.2. Summary of Data Used

A robust analysis of a company or network's carbon impact needs to be based on quality data. In this regard, xDAI provided a dataset that has enabled Offsetra to calculate the carbon impact of their Scope 1, 2 and 3 emissions. The analysis would have produced more concrete results had more precise information been available on the location of xDAI network activity, and a more detailed breakdown of what server was used, and whether they were remote servers or local servers.

5.3. Recommendations for Future Data Collection

Erring on the side of caution, Offsetra used an averaged assumption of electricity usage and the localised carbon impact for hardware requirements, while taking into account the lifecycle costs of this equipment. This provides a robust solution to account for emissions from the network's physical infrastructure. In the future, anonymised survey data from nodes could be used to better understand the specific hardware makeup of the xDAI's entire network and the geographical locations of network activity.

5.4. Recommendations for Reducing Carbon Impact

There are two important components to achieve carbon neutrality moving forward. The first is understanding emissions hotspots and where reductions can be made and the second is in regards to compensating for the emissions from xDAI's business operations.

Given that xDAI is already a very efficient Proof of Stake network, and the network activity and hardware is distributed in nature, it is difficult for xDAI to further reduce emissions here. A key action to take would be assessing how node operators could be incentivised to purchase renewable energy and verifiably report this (or, choose server providers which utilize renewable energy).

The employees of the network are also fully remote, and the emissions associated with corporate activities from the network are already low and it may require significant investment to reduce them further. Staff travel was not considered in this analysis, although it is worth noting that if xDAI employees have done international trips that are not accounted for here, this may significantly increase the emissions from xDAI's corporate activities.

Carbon offsetting enables entities to compensate for the unavoidable carbon emissions they cause. If xDAI wish to pursue a carbon offsetting solution then it is recommended that at a minimum the partner selected can offer verified carbon offsets that have been audited and certified by a Carbon Registry (e.g. Gold Standard, Verra, Climate Action Reserve etc) to cover the emissions of the network. Using such standards gives xDAI a guarantee that the investments into carbon mitigation projects are robust and guaranteed. Once high-integrity carbon offsets are invested in xDAI can then consider additional investments into other projects and causes that may fulfil the Corporate Social Responsibility objectives of the organisation.

5.5. Recommendations for Achieving Carbon Impact

Looking forward, xDAI should begin to build a long-term emissions profile of its Scope 2 and 3 emissions. This could be done in the form of a quarterly or annual report. This will enable xDAI to identify any areas that are becoming more carbon intensive over time, and where action should be focussed. Consistent reporting can be used to demonstrate the company's commitment to environmental action, and critically it can be used to raise awareness of others in the space around the importance of assessing their carbon impact and taking action.

Sources

1) *Estimating Energy Consumption & GHG Emissions for Remote Workers - White Paper*. Anthesis. February, 2021. https://www.anthesisgroup.com/wp-content/uploads/2021/02/Anthesis_-Remote-Worker-Emissions-Methodology_Feb-2021.pdf

2) *Energy Footprint of Blockchain Consensus Mechanisms Beyond Proof-of-Work. UCL. 2021* http://blockchain.cs.ucl.ac.uk/wp-content/uploads/2021/09/UCL_CBT_DPS_Q32021_updated-1.pdf