Audit of Performance, Carbon Intensity, and Green Hosting based on 21 Municipality Websites in Akershus county, Norway

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Abstract

The web consumes significant amounts of energy for hosting, storage, and servers. This makes web sustainability an increasingly critical concern at both national and international levels. Minor improvements at page level, can positively impact the amount of energy savings. Such changes include focus on renewable energy hosting. Sustainable web design will help us cut down on our emissions.

Sustainable web design is particularly important for public sector web services such as municipalities. They provide a crucial role in conveying information to the public. Therefore, this paper focuses on auditing all the 21 municipalities found in Akershus county, using a multi-run Lighthouse pipeline. Auditing each municipal homepage with three cold Lighthouse CLI runs and reporting the median for each key metric. Estimated per-page-view transfer emissions from the median total byte weight using @tgwf/co2, reporting grams of CO2e. Verification of green hosting was done using the Green Web Foundation Check API while simultaneously analyzing https://<domain>/carbon.txt for transparency signals. The JavaScript payload was analyzed by summing the JS transfer bytes and visualized its relationship to CO2 emissions.

Key findings reveal a lack of concern for sustainability. Out of 21 municipalities only five were hosted using green energy. None of the municipalities showed evidence of carbon.txt. The average performance score was 62,57 out of 100. Heaviest transfer bytes measured were 6.76 MB for Rælingen. While the lowest measured municipality was Lunner, 0.92 MB.

The results show a clear variation in the success of implementing sustainable design choices among audited municipalities. The purpose is showcasing proposed improvement areas for each municipality.

CCS Concepts

• **Social and professional topics** → **Sustainability**; • **Information systems** → *Web applications*; • **Computing methodologies** → *Model development and analysis*; • **Computer systems organization** → Cloud computing.

Keywords

Carbon footprint, Sustainable Web Development, Greenhouse gas emissions, Green hosting, Sustainability awareness

1 Introduction

The World Wide Web was a genius invention that shaped the way society evolved. This crucial invention has now become a big source of our greenhouse gas emissions. According to the International Energy Agency data centers and data transmission networks are responsible for 1% of energy-related GHG emissions [1]. Data centers run on large amounts of energy. Which is often met by burning fossil fuels. In 2021 The Green Web Foundation found out that 60% of the worlds electricity came from fossil fuels [3]. Fossil fuels are the least sustainable sources of electricity, they keep on ruining our planet.

All services relying on data centers must take accountability and make more sustainable choices. The responsibility of caring for our planet is a global action that needs to be taken seriously. Even though lowering our emissions is a well-known goal, not enough actions are made. The objective being to reach the Paris agreement goal of limiting global warming to 1.5 °C. This proposes the responsibility towards municipalities to act. Which forms the research question:

To what extent do municipal websites in Akershus follow sustainable practices, in terms of performance metrics, carbon emissions, hosting choices and adherence to Web Sustainability Guidelines?

The results from auditing all municipalities within a single county, provide meaningful insight into web sustainability. These municipalities share similar regulatory frameworks, regional policies, and access to comparable infrastructure and resources. This makes it possible to identify patterns and differences that are not for certain caused by national or external variables, but rather by local choices in website design, hosting, and sustainability strategy. Which in return means analyzing a complete regional ecosystem rather than isolated cases.

The audit offers a representative and fair comparison, highlights best practices within the same context. This reveals potential inequalities or improvement opportunities across municipalities. Such findings can therefore be supported by regional policy development, encourage collaboration, and provide a blueprint for scaling the audit to a national level. In order to support the national transition towards online sustainability. Achieving sustainability in web applications requires not only technical efficiency, but also a understanding of users. The goal is to create web applications that are not only sustainable, but also accessible and promote climate justice.

2 Background / Related Work

Research on sustainable web design has grown significantly in recent years, focusing on both environmental impact and technical performance. Studies such as Istrate et al. (2024) quantify the global carbon footprint of digital content, while highlighting the relevance of efficient web development. Other research emphasizes green hosting practices, with datasets like the Green Web Foundation and the analyses done in the Web Almanac 2024 providing benchmarks for renewable energy use in websites. Green hosting involves making sure the data centers which host your application, are running on clean and renewable energy. Which will make an impact on the CO2 emission. Green Web Foundation is providing a dataset with the information of all verified green hosting providers [3].

To grasp the meaning of a sustainable web, we need guidelines to follow. The World Wide Web Consortium (W3C) has created The Web Sustainability Guidelines (WSG) which can be used in the making of web products and services. With the intention of making smarter and more sustainable choices not only for the planet but also for people. WSG goals are applicable by creating a mix of automated machine testing and human evaluation. Their foundation for web sustainability is presented in six simple principles: clean, efficient, open, honest, regenerative, and resilient [4]. Their role is to represent what it takes to make web products and services sustainable.

Sustainability is a broad field with a core in tracking carbon emission. Carbon.txt is a single, discoverable location on any domain. Created by The Green Web Foundation, to ensure public, machine readable sustainability data readings [2]. It gives a company the tools to publish their data. While making is easy for costumers to navigate to those disclosures.

Human and organizational factors are also critical. Mosca et al. (2024) show that factors such as developer awareness and design decisions influence sustainability adoption. Auditing tools like Lighthouse, can help automate the auditing process. A sustainability audit is defined as an assessment of a service´s practices, processes and performance. All to ensure they operate in an environmentally responsible manner. The audits help showcasing areas for improvement and sustainability standards.

Previous audits have measured public websites' carbon emissions and efficiency. The core issue is the limited research on municipal websites in Norway that combines both performance metrics and hosting sustainability while ensuring reproducibility.

This work addresses these gaps by auditing all municipalities within a selected county, analyzing performance, carbon footprint, and green hosting adoption in a reproducible manner.

3 Methodology

The audit was conducted on all of the 21 municipalities in Akershus county, which are as stated:

- https://www.asker.kommune.no
- https://www.aurskog-holand.kommune.no
- https://www.baerum.kommune.no
- https://www.eidsvoll.kommune.no
- https://www.enebakk.kommune.no
- https://www.frogn.kommune.no
- https://www.gjerdrum.kommune.no
- https://www.hurdal.kommune.no
- https://www.jevnaker.kommune.no
- https://www.lillestrom.kommune.no
- https://www.lunner.kommune.no
- https://www.lorenskog.kommune.no
- https://www.nannestad.kommune.no
- https://www.nes.kommune.no
- https://www.nesodden.kommune.no
- https://www.nittedal.kommune.no
- https://www.nordrefollo.kommune.no
- https://www.ralingen.kommune.no
- https://www.ullensaker.kommune.no
- https://www.vestby.kommune.no
- https://www.as.kommune.no

3.1 Data Collection

For each website, the script executed three headless Lighthouse runs. From each run it extracted the category performance score on a scale from 0 to 1. Based on these metrics FCP, LCP, Speed Index, TBT, CLS, total and JS bytes, and the request list. All individual run reports are saved under evidence/lighthouse/runs. A synthesized median report per site is lastly written to evidence/lighthouse/<domain>.json. A single consolidated row per site is written to evidence/summary.csv (and summary.json).

The audit included some limitations, such as only having a single snap-shot of the 21 municipality websites, global-average CO2 factors and possible temporal variability.

3.1.1 Medians and Co2 models. Medians were computed across the three runs for all numeric metrics, such as transferBytes = median of total-byte-weight across runs. The performance score was then exported on a 0–100 scale. For all nonaggregatable data such as request list and JS breakdown, the script selects the run whose request count is closest to the median count. Then sums JSBytes from script-like requests. The anticipated CO2 emissions based on two models (Onebyte and SWD models) are calculated from the median transferBytes. The CO2 OneByte model is data-driven, while SWD model incorporates hosting sustainability factors into the calculation. Which means that the SWD model often produces lower CO2 estimates for websites hosted by a certified green provider. This causes an issue when the transferred data volume is similar. Therefore, using a combination of both models to gather estimated CO2 emissions will give more accurate results.

3.1.2 Tools. Audits ran using Node.js ES modules. Lighthouse CLI and headless Chrome integrate directly with Node, lowering the need for wrappers. Which also queried the Green Web Foundation API and checked for presence of carbon.txt. Python scripts (scripts/python/*) were used to produced the figures and tables from the CSV file (summary.csv). Python (pandas and altair) was used as a tool for aggregation and visualization. A clean separation between coding languages and their roles made it easier to debug and simplified coupling.

4 Results

The results of the sustainability audits conducted on all municipal websites in Akershus county, totaling to 21 website URLs.

4.1 Median metrics and aggregated results

Provided metrics presented into averages, minimum and maximum scope. Run across all municipality websites, then summarized into aggregated results.

Table 1: Aggregated results across all municipalities

Metric	Sites	Mean	Min	Max
cls (unitless)	21	0.0166	0.0	0.2729
co2_onebyte_grams (grams)	21	0.7	0.3	2.0
co2_swd_grams (grams)	21	0.9	0.4	2.6
fcp_ms (ms)	21	5886.6	2340.5	14555.4
jsMB (MB)	21	0.74	0.25	1.63
lcp_ms (ms)	21	11141.6	5200.6	31341.2
performanceScore (score (0–100))	21	61.0	42.0	74.0
requests (count)	21	53.0	34.0	96.0
speed_index_ms (ms)	21	6524.7	2427.2	14555.4
tbt_ms (ms)	21	101.7	0.0	258.0
transferMB (MB)	21	2.4	0.92	6.76

4.2 Performance

Lighthouse has a performance score scope in the user interface from 0 to 100 which then is stored as a scale from 0-1 in JSON. The script turns that into a 0 to 100 integer or returns null if unavailable.

Each municipality is then scored from 0 to 100 based on the median from three Lighthouse runs, which is represented in table 1. Showcasing the variations in performance scores for each municipality.

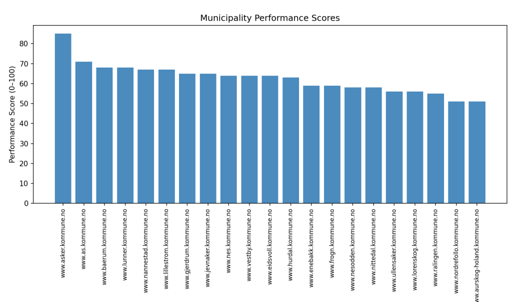

Figure 1: Performance scores across all municipalities audited

4.3 Green hosting

Each municipality was check for sustainable hosting, using the Green Web Check API, then cross verified with the Green Web directory. Only 23.81% of municipalities were hosted using green and renewable energy (Asker, Bærum, Jevnaker, Lunner, Vestby). Despite presence of green hosting verification, none of the municipalities published carbon.txt. A representative example of the Green Web Check API output is shown in Figure 3.

4.4 The fifteen heaviest municipality websites

The audits showed which municipality websites were the heaviest emitters based on transfer size. Heaviest median transferBytes were 6.78 MB produced by the Rælingen municipality website.

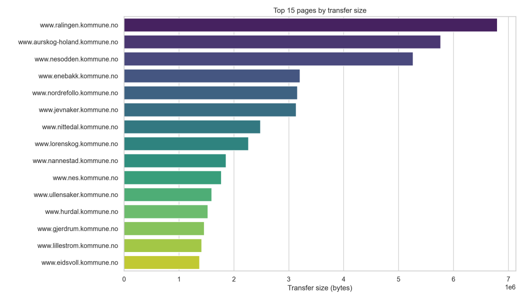

Figure 2: Chart of the fifteen heaviest municipality websites

5 Discussion

5.1 Interpretation of Findings

The results from auditing all selected municipalities reveal considerable opportunities for improving web sustainability. Merely 23.81% of municipalities were hosted using a verified green energy infrastructure. None of the audited websites showed evidence of a published `carbon.txt` file. Performance metrics such as page weight, number of requests, and JavaScript usage were consistently higher than the benchmarks reported in the Web Almanac 2024. Stating that web page weight should be ideally kept below one MB. Which, leads to results indicating inefficiencies in both design and chosen implementation. These findings highlight that municipal websites might prioritize content conveyance and infrastructure over environmental performance.

From a sustainability perspective, large page sizes and excessive resource usage directly translate into higher energy consumption and carbon emissions (Istrate et al., 2024). Low adoption of green hosting demonstrates that municipalities face certain trade-offs. These include choosing between cost, convenience, and environmental responsibility (W3C Sustainable Web Interest Group, 2025). Moreover, the absence of `carbon.txt` files points to limited transparency. This results in reducing the ability for users and auditors to verify environmental claims. These results suggest that achieving sustainable web practices requires attention not only to technical optimizations but also to organizational awareness and governance (Mosca et al., 2024).

5.2 Comparison with Benchmarks and Literature

Comparing the findings with prior research further contextualizes the final results. While global web performance averages reported in the Web Almanac 2024 provide a useful starting benchmark, audited municipal websites frequently exceed these metrics, highlighting inefficiencies.

The sustainability audit of municipalities in Akershus, highlight the ongoing challenges with sustainable web development. The estimated carbon emissions and page weights observed in this study, while variable, reflect a broader global pattern of environmental impact all from digital content consumption. Demonstrating that digital content usage worldwide contributes significantly to energy demand and carbon emissions. While emphasizing that seemingly small optimizations in page weight or script efficiency can have meaningful effects at scale [5]. In this context, the calculated differences among municipal websites in terms of CO2 per page view, illustrate how local design and infrastructure decisions can contribute to cumulative global sustainability outcomes. This reinforces the concept that improving website efficiency is not only a technical concern, but rather a part of a wider environmental responsibility.

When contextualizing these results, it is useful to compare them with broader web trends reported in the Web Almanac. The Almanac indicates that many websites globally still highly rely on large JavaScript bundles, heavy multimedia assets, and unused CSS. It all comes back to contributing to increased page weight and carbon emissions [7]. The findings from this audit are consistent with these trends, with several municipal websites showing higher-than-average page sizes and not optimal resource usage. As for the auditing method, using a median-of-three structure reduces run-to-run noise and improves reproducibility. It also highlights the potential for performance improvements through better front-end optimization, caching strategies, and removal of redundant assets.

Despite the availability of green hosting datasets from the Green Web Foundation (2025), adoption remains low, underscoring a gap between technical possibility and practical implementation. The Web Sustainability Guidelines (WSG) developed by the W3C provide clear principles for sustainable web design, combining automated evaluation and human review (W3C Sustainable Web Interest Group, 2025). However, the audit shows that these guidelines are not consistently applied, reflecting challenges in organizational uptake and prioritization.

Auditing municipal websites presents additional difficulties compared to other academic or public web sites. Variability in hosting providers and limited budgets complicates both the implementation and automated assessment. Additionally, website content and architecture frequently change, meaning that audits provide only a snapshot in time.

Sustainability is furthermore a question of technical efficiency but also of user interaction and it´s behavioral influence. One can argue that digital technologies can advocate users into energy-efficient behaviors. Using interfaces that are strategically designed and transparency is provided for users [6]. The municipal websites showed a clear lack of carbon transparency, which included the absence of carbon-related information. Which with evidence suggests that users are largely unaware of the environmental impact created by their interactions. Integrating sustainability oriented interface elements such as notifications about energy consumption or prompts to minimize data usage could improve transparency. While also giving users a nudge in the direction of more sustainable behavior. This aligns with the broader principle that web design can actively support environmental goals, not merely passively reduce emissions.

5.3 Limitations

Several limitations should be considered when interpreting these results. Firstly, the audit covers only one Norwegian county, so an accurate overview of all municipalities nationally is limited. Secondly, the metrics rely heavily on automated tools such as Lighthouse and the `@tgwf/co2` model. While these tools are created to be robust, they may not capture all aspects of sustainability. This includes a difficulty in capturing dynamic content and back-end infrastructure. Lastly, the audit represents a single point in time, and websites may be updated, optimized, or migrated to green hosting at any time. Including CO2 emissions calculation limitations due to global average assumptions. Yet, despite these limitations, the findings from the audit provide a meaningful and reproducible baseline for understanding municipal web sustainability.

5.4 Recommendations

Based on the findings, several practical recommendations emerge. Municipalities should optimize page weight, reduce unnecessary scripts, and compress images to minimize energy consumption. Adoption of verified green hosting providers should be prioritized when possible. Publishing a `carbon.txt` file would increase transparency and allow users, auditors, and researchers to verify sustainability claims.

5.5 Future Work

Future research could expand the audit to additional counties and include monitoring to capture changes over time. Even more advanced methods for auditing could incorporate analysis of dynamic content and user behavior to understand how design choices influence environmental impact. Furthermore, policy interventions and governance strategies should be investigated to evaluate how institutional incentives affect sustainable practices. This ongoing research will further enhance the understanding of sustainable web development and promote actionable improvements on a national level.

5.6 Concluding Reflection

In conclusion, auditing municipal websites provides valuable insights into web sustainability. Helping reveal significant technical inefficiencies and low adoption of green hosting practices. However, the results also emphasize that sustainability is a multi dimensional challenge. A challenge requiring a mix of technical, organizational, and behavioral interventions. By combining reproducible auditing methods with awareness of guidelines, such as WSG and datasets like the Green Web Foundation, municipalities can take concrete steps towards environmentally responsible development. The audit framework presented here can serve as a foundation for continuous monitoring, improvement, and broader adoption of more sustainable practices. All this while simultaneously enhancing usability and transparency for all users.

6 Conclusion

This study evaluated the sustainability of municipal websites in Akershus. The evaluation was completed by analysing performance metrics, estimating carbon emissions and lastly checking alignment with sustainability guidelines. Revealing a gap between present municipal web practices and standards for sustainable web services. Numerous municipality websites scored heavier than recommended benchmarks, resulting in higher estimated emissions and lowered performance. A small fraction of municipalities implemented green hosting. None of the municipalities offered transparency through a carbon.txt file. Which indicate a lack concern for renewable energy reporting and sustainability focus.

The results demonstrate that improving municipal web sustainability requires more than technical optimization alone. Improving also depends on strategic decisions, organizational awareness, and a focus on guidelines such as the Web Sustainability Guidelines. Increased transparency and the shift towards hosting on renewable energy offer clear steps towards improvement.

The purpose of this audit is to create reproducible methodology and dataset that can help support future evaluations of public web services. Further work would focus on expanding the scope to additional counties to reach a broader spectrum. While also comparing changes over a longer amount of time. Ultimately, sustainable public websites benefit the environment and user experience. While also highlighting their responsibility so they can lead by example in the transition towards a sustainable digital future.

A Supplementary Evidence

A.1 Green Hosting API Response Screenshot

Figure 3: Screenshot of Green Web Check API response for Lunner municipality.

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