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Green Web Meter: Structuring and Implementing a Real-Time Digital Sustainability Monitoring System

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Abstract: The central aim of this paper is to present the Green Web Meter software, which is designed to support the measurement of the digital ESG performance of websites and web apps, as well as providing sound-based analytic tools for improving their overall quality. In this work, we will discuss the process our research team adhered to in order to provide a basic structure to the general framework of our tool, select a consistent set of KPIs that are suitable for automated real-time tracking, and determine the proper calculation methods to compute the final scores on which the ESG assessment is based. Specifically, we began from the analysis of the UNI PdR 147 guidelines on digital sustainability, highlighting the relevance of the quality construct, and subsequently selected three quality assessment models (E-S Qual, Sitequal, and Webqual 4.0) to define the core references to structure the basic framework. Starting from this general perspective, we proceeded to define the eight related KPIs and the individual scores based on the automatic calculations.

Keywords: digital sustainability; website quality; real-time monitoring; website CO_2 emissions; digital ESG evaluation; digital carbon footprint

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1. Introduction

The scientific and regulatory debate on sustainability is gaining increasing priority at the international level. Initiatives such as the United Nations 2030 Agenda for Sustainable Development and the European Green Deal legislative package exemplify this renewed sensitivity. These efforts are leading the way for institutions and scientific committees to support policy-making activities.

In particular, the aforementioned Green Deal, the European strategy for ecological transition (aligned to the 2015 Paris Agreements), aimed at identifying strategic areas within the European economic landscape and structuring interventions consistent with the goal of achieving carbon neutrality by 2050 [1]. However, the Fit for 55 regulatory packages, a key component of the European climate strategy mainly related to the transport, construction, and agriculture segments, surprisingly lacks sufficient awareness regarding the impacts of the digital economy.

A 2019 report from The Shift Project [2], a Parisian think tank, highlights that the projected global digital emissions for 2020 would be equivalent to the total emissions of the entire Middle East (based on the 2017 data). According to the predictive model adopted, digital technology emissions are constantly growing, reaching a share equal to 8% of the global total (equivalent to the CO2 produced by all the light vehicles in use in 2018). Although more recent data from the Tallin University of Technology scale down this impact (37% in 2024), these levels of consumption are still significantly higher than the emissions of the entire aviation sector, according to the International Air Transport Association, in 2019 (2% of the global total).

These pieces of evidence call for greater attention to be paid to the topic of digital sustainability, a concept that emerged as early as 2007 with Kevin Bradley's work titled

"Defining Digital Sustainability" [3]. Starting from this contribution, it is appropriate to delve into the evolution over time of the main perspectives and argument streams that have helped to structure the concept of digital sustainability.

As an expert in the conservation of digital resources, Bradley [3] emphasises the technical longevity of digital information, from data storage on appropriate hardware devices to the standardisation of file formats and identification schemes for data structures. A broader view on the subject can be found in the work of Dapp [4], who approaches the issue from the perspective of digital resource management, asserting that "Digital resources are handled sustainably if their utility for society is maximized so that digital needs of contemporary and future generations are equally met. Digital needs are optimally met if resources are accessible to the largest number and reusable with minimal restrictions. Digital resources encompass knowledge and cultural artifacts represented in digital form e.g., text, image, audio, video, or software". Compared to this approach, it is possible to observe how more recent developments in the debate have tended to shift the focus to the supportive role of digital aspects in sustainable development, as demonstrated in publications by various authors including Konys [5], Sparviero and Ragnedda [6], and George, et al. [7]. The latter contribution links the concept of digital sustainability to the implementation of technologies that create, use, transmit, or obtain electronic data for promoting and advancing the 2030 Agenda goals.

A reunification of the two perspectives identified so far can be observed in the position of Stefano Epifani, head of the Digital Sustainability Foundation and author of the book titled "*Digital sustainability: why sustainability cannot do without digital transformation (in Italian)*" [8], according to whom digital sustainability both relates to the role of digital technologies as tools for sustainable future development and the direction to be chosen regarding digital innovation so that it is grounded in sustainability criteria.

Despite the richness of the debate on the topic, the data indicate the need to increase its resonance among broader audiences. For example, the findings of the 2022 DiSI Observatory survey—coordinated by the Digital Sustainability Foundation—show that only 26% of the analysed sample is aware of the role of digital aspects in sustainability, competent in the sustainable use of digital technologies, and inclined to adopt behaviours consistent with the levels of awareness and competence shown.

For this very reason, our research team opted to offer a contribution, which is primarily aimed at raising awareness about digital sustainability in the corporate sector, as well as boosting competence and providing orientation toward consistent behaviours related to website and web app development and management. To this end, we chose to leverage the transformative potential of Industry 4.0 technologies—namely Internet of services (IoSs) and artificial intelligence (AI) [9]—and develop a real-time digital sustainability monitoring software as the evidence presented in Vinuesa et al. [10] and the UN SDG Digital program's research suggest that AI and digital technologies may effectively act as enablers for progressing the United Nations' Sustainable Development Goals.

In this regard, we would like to underline that our effort seeks to go beyond the focus on digital decarbonisation [11] and move toward an integrated view of digital sustainability, taking account of the full scope of the ESG paradigm, which encompasses the environment, society, and governance.

In this article, we would like to discuss the Green Web Meter monitoring software (www.greenwebmeter.com (accessed on 5 July 2024)) by illustrating the steps our research team followed, from the definition of the general structure of the model to the explanation of the calculation methods used to determine the final digital ESG scores (Figure 1). Therefore, this work aims to provide answers to the following research questions:

i. How did we select the basic framework and key aspects for structuring the Green Web Meter?
ii. Which specific KPIs were selected for monitoring purposes?
iii. How does the Green Web Meter keep track of the KPIs and compute scores for each one of the sustainability pillars?

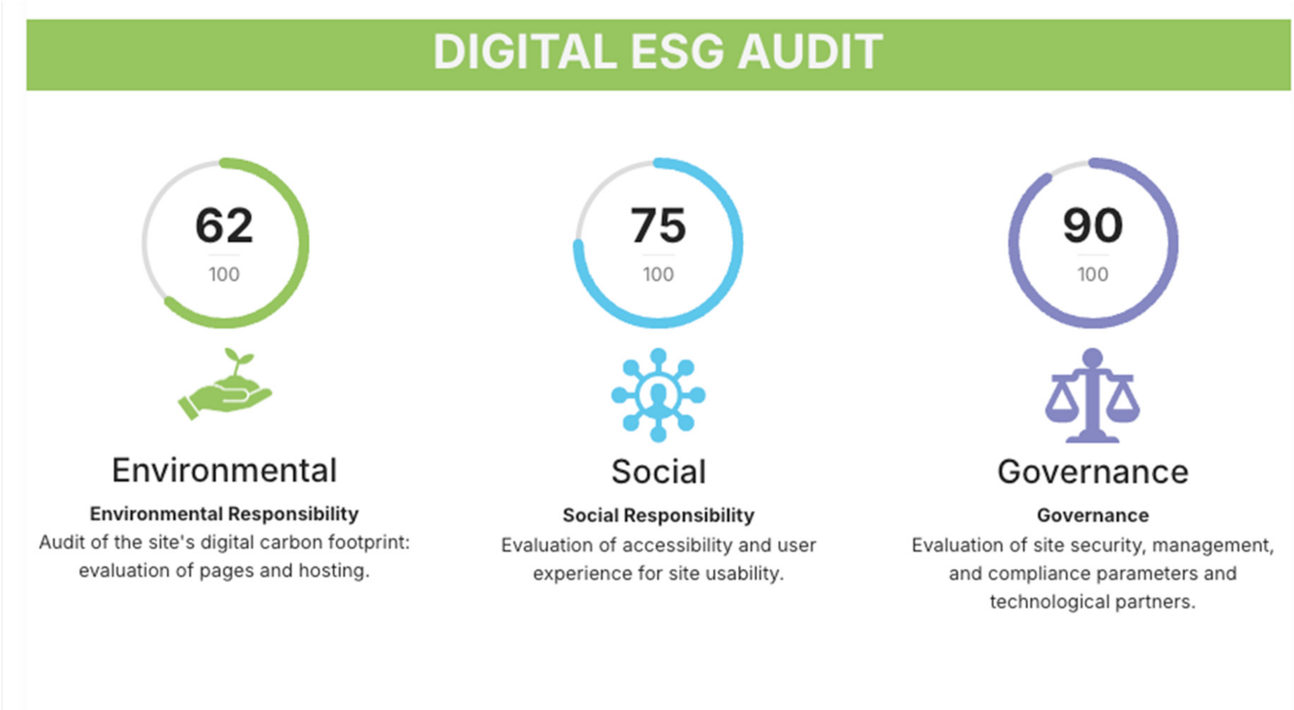

Figure 1. Green Web Meter Environmental, Social, and Governance (ESG) scores. *Modified and adapted from: www.greenwebmeter.com (accessed on 5 July 2024).*

2. Literature Review

With the purpose of developing a proper model for monitoring the digital sustainability of websites and web apps, we undertook the initial step of analysing the Italian National standard UNI PdR 147:2023 [12]. This document offers organisations and practitioners a framework for the sustainable management of digital transformation projects using a step-by-step approach throughout the project lifecycle. In this regard, we consider it useful here to refer in particular to the monitoring phase (phase 4), carried out in parallel with the execution phase (phase 3), according to the aforementioned guidelines, which is centred on the evaluation of results and performance quality.

To identify the main components of the quality construct, we started by performing a technical and scientific literature review regarding website quality and the methods used to assess it. Then, we opted for the selection of three specific models that we used as a starting point: namely E-S QUAL, SITEQUAL, and WebQual (its 4.0 version). Starting from the previous service quality evaluation frameworks, such as SERVQUAL, the structures presented in Tables 1–3 aim to define the core components of the quality construct in the web environment. We present these quality evaluation frameworks below.

Table 1. The E-S QUAL model.

Parameter	Description
Efficiency	Ease of use and speed of the website (e.g., information organisation, ease of finding information, page loading speed, and transaction completion speed).
Satisfaction	Truthfulness of statements about order delivery times and availability of items.
System availability	Correct functioning of the website (e.g., functional fluidity, absence of crashes and system blocks).
Privacy	Security and protection of consumers' privacy.

Table 2. The SITEQUAL model.

Parameter	Description
Ease of use	Usability of the site and ease of access to relevant information.
Design aesthetics	Creativity, use of colour, and visual quality of multimedia assets.
Process speed	Speed, interactivity, and responsiveness.
Security	Security of personal and financial data.

Table 3. The WebQual 4.0 model.

Parameter	Description
Usability	Ease of use, clarity and comprehensibility of interactions, navigability, attractiveness of display, appropriateness of graphic layout, clarity in layout and information hierarchy, ease of finding the website address, and completeness of information on the website.
Information quality	Reliability of information, ability to provide updated information, comprehensibility and readability of information, ability to provide detailed information, relevance of information, accuracy of information, and presentation of information in the appropriate format.
Interaction quality	Website reputation, transaction security, perception of security in providing personal data, sense of community, ability to attract interest, openness to feedback from users, and reliability in transactions of goods or services.

3. Results

By analysing these models and the related scientific contributions in depth [13–15], it clearly stood out that all three can be considered as reliable frameworks to provide information on user perception of website quality. Moreover, we can add that the statistical inferences tested in the first two models underlined solid correlations between users' quality perception and the website loyalty intentions.

However, since our goal is to tailor a model based on cross-sectional references for evaluating website quality, rather than just taking account of the e-commerce segment, the research team opted to conduct a synthesis approach based on the following considerations:

- The efficiency and satisfaction aspects from the E-S-QUAL model are the most critical factors in determining a website's service level as they exhibit strong correlations not only with the overall quality construct but also with user loyalty.
- The SITEQUAL model's usability and security indicators emerged as the most impactful criteria on consumer perceptions and attitudes.
- The information quality index of the WebQual 4.0 model does not significantly affect the user satisfaction levels when interacting with a website.

These preliminary evaluations allowed us to identify the following key aspects for providing the basic structure of the Green Web Meter software, allowing us to respond to the first research question (i.; see Introduction). These elements, which will be discussed in depth later on, are the following:

- performance efficiency;
- usability; and
- security and interaction quality.

After analysing the key references for website quality (performance efficiency, usability, security, and interaction quality), the team worked on harmonizing the indicators and providing a structure to the initial framework to guide the subsequent monitoring operations of the Green Web Meter software, as presented in Table 4. This process essentially consisted of the following:

- Identifying the individual components of the "overall quality" construct that are transversal in nature, meaning they are not exclusively applicable to the e-commerce context (e.g., reliability and timeliness of on-site transactions).
- Integrating these components with the UNI PdR 147 guidelines applicable to the development of websites and web apps.
- Reordering all the various components, aligning them with the reference points identified through the analysis of the contributions mentioned previously (E-S QUAL, SITE-QUAL, and WebQual 4.0) and the digital sustainability targets set by the UNI guidelines.

Table 4. The digitally sustainable website's quality.

Parameter	Description	Related UNI PdR 147:2023 Target(s)
Performance efficiency	Speed and fluidity; digital resources' use efficiency (asset sizing); energy efficiency and carbon efficiency (principles of sustainable web design)	7.2: Develop software with a reduced energy impact
Usability	Accessibility	10.1: Develop inclusive, accessible, and usable digital services
Security and interaction quality	Security; privacy; reputation	9.2: Create secure and resilient digital infrastructures 10.2: Develop digital services that respect users

Based on this general framework, our team started developing the Green Web Meter software, aiming at providing the automatic and real-time monitoring of the various components of service quality and digital sustainability through the following operations (research question ii.):

- The evaluation of the main Core Web Vitals parameters—namely the Largest Contentful Paint and Total Blocking Time—related to the loading performance and fluidity of interactions with digital elements (reference KPIs: speed and fluidity).
- The measurement of the size of the digital resources integrated into the pages (reference KPIs: efficiency in the use of digital resources).
- The estimation of the electricity consumption per page view, on the end-user side, and verification of any support for green hosting services, powered by renewable energy (reference KPIs: energy efficiency).
- The estimation of the scope 3 emissions (related to the use phase of products and services as established by the GHG Protocol) based on the electricity consumption data and subsequent calculation of the carbon footprint (reference KPI: carbon efficiency).
- Accessibility compliance and best practice checks based on the Web Content Accessibility Guidelines. In particular, these guidelines include specific measures aimed at users with visual disabilities, such as the inclusion of alternative text for images that enable screen readers to provide proper information about the visual asset content (reference KPI: accessibility).
- The verification of the adoption of the HTTPS protocol, the identification of common vulnerabilities—such as the presence of mixed content, i.e., HTTP resources within HTTPS pages and cross-origin links, i.e., hyperlinks that point to resources located on a different domain from the one of the web page that contains them—and any critical errors in the development of the website, such as the visibility of the server's data in header responses, i.e., specific pieces of metadata sent along with an HTTP response from a web server to a client, and email privacy misconfigurations (reference KPI: security).
- The identification of the visit tracking systems integrated into the website or web app, such as Google Analytics or Matomo (reference KPI: privacy).
- Checking the main components of web reputation [13], which include the search engine optimisation (SEO) operations and social media presence, with the relative integration of social channels within the website or web app (reference KPI: reputation).

Finally, it should be noted that the Green Web Meter software, as a tool designed to facilitate reporting processes and provide useful information for assessing digital sustainability performance, is arranged in a threefold structure (as indicated in Table 5) in accordance with the ESRS guidelines adopted as a reference by the EU's 2022/2464 Directive [16]. By linking each of the KPIs outlined so far to the relating ESG pillar, the software provides the final score's attribution for each criterion.

Table 5. The Green Web Meter monitoring framework (ESG criteria, KPIs, and derived scores).

ESG Criterium	KPI	Derived Scores
Environment (E)	Speed and fluidity	UX score
	Digital resources' use efficiency *(asset sizing)*	Page weight optimisation score
	Energy efficiency	Green hosting
	Carbon efficiency	Carbon footprint mitigation score
Society (S)	Accessibility	Accessibility score
		Best practice score
	Reputation	SEO score
		Social media presence
Governance (G)	Security	HTTPS encryption
		Mixed content
		Unsafe cross-origin links
		Public server visibility
		Email privacy
	Privacy	Visitor tracking

As stated in the Introduction, the Green Web Meter's general framework is specifically tailored to represent an alternative to the majority of the digital sustainability monitoring tools available on the market (such as *Digital Beacon (Digital Beacon v1.13.2. Calculate the environmental impact of a web page, see the breakdown and learn what measures can be taken to improve it. Available online: https://digitalbeacon.co/, accessed on 5 July 2024), Mightybytes's Ecograder (Ecograder. Reduce emissions, improve performance, meet your website goals faster. Available online: https://ecograder.com/, accessed on 5 July 2024), and Wholegrain Digital Website Carbon Calculator (Wholegrain Digital Website Carbon Calculator v3. What's Your Site's Carbon Footprint? Available online: https://www.websitecarbon.com/, accessed on 5 July 2024)* [17], providing additional information aside from the estimation of the energy consumption and the digital carbon footprint. In addition, as opposed to the aforementioned solutions, the Green Web Meter is able to perform screenings of the entire structure of websites and web apps rather than relying on a single-page approach, as we will illustrate in the following section.

4. Material and Methods

To provide further details about the Green Web Meter monitoring tool, we present here a brief summary of the procedures involved in the process, starting from the insertion of the main URL, i.e., the homepage's address, in the proper section of the interface. As the end-user completes this preliminary step, our software will be able to perform the following tasks:

- identifying the site map and extracting the URLs that make up the website or web app, thanks to a specific anti-ban script simulating web browsers' operations and performing nearly simultaneous crawling activities, on the order of milliseconds, from different IPs;

- direct call to our proprietary script, simulating a browser's activity, and subsequent retrieval of the digital assets for each page, such as JavaScript and CSS files, images, videos, fonts, and so on;
- analysis of the digital resources aimed at evaluating each page's performance; and
- data aggregation, score calculation, and final report generation.

Score verification and Non-Fungible Token (NFT) badge assignment (Figure 2) for those websites and web apps that reach at least 60 points for each of the three ESG criteria (environment, society, and governance).

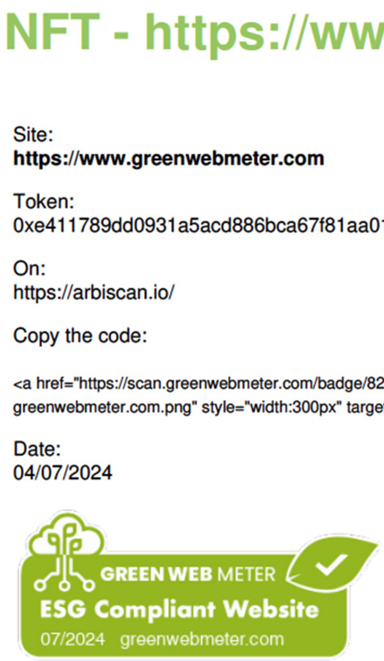

Figure 2. Green Web Meter Non-Fungible Token (NFT) badge. *Modified and adapted from: www.greenwebmeter.com (accessed on 5 July 2024).*

The calculation methods for each score and KPI the Green Web Meter model is based on, responding to the third research question (iii.).

4.1. Green Web Meter Score (E): Environmental Criterion Assessment and Evaluation

The Green Web Meter software calculates the environmental score based on the following model:

$$GWM(\%) = (CFM \times 0.40) + (PWO \times 0.40) + (GH \times 0.12) + (UX \times 0.08) \quad (1)$$

where GWM is the Green Web Meter Score (%), CFM is the carbon footprint mitigation score (%), PWO is the page weight optimisation score (%), GH is the green hosting (%), and UX is the UX score.

Carbon footprint mitigation score: The "carbon footprint mitigation score" represents the degree of minimisation of greenhouse gas emissions associated with the operation of a website or web app. In accordance with the model proposed by the Sustainable Web Design project—in its third version—we take as reference variables the following:

- The total amount of data transferred during a page view (in GB), detected in real time by the Green Web Meter software.
- The ratio between the electricity consumption attributed to network operation in 2023 (hosting, servers, network nodes, and content delivery networks) and the consumption attributed to end-user devices, estimated at 0.81 kWh/GB [18]. It is worth noting that the data considered—also validated by Bonetti [19]—are variable over time due to

technological evolution of the network infrastructure, efficiency improvements in the design of websites and web apps, and client-side devices.

- The ratio between the energy consumption of new visitors and returning visitors, with an attributed modifier of 0.7 *(own estimate)*, which, according to Andrae (2020), respectively, account for 75% and 25% shares.
- The global average of carbon intensity—i.e., grams of CO2 equivalent per kilowatt-hour—estimated at 442 g/kWh [18]. Again, it is noted that the data vary over time and by geographical area, as clearly indicated by the Electricity Maps' data visualisation project.
- A green hosting factor—detected through API call to the Green Web Data Set and applied in case the website or web app relies on servers powered by renewable energies, whose production determines lesser environmental impact compared to non-renewables (fossil fuels, carbon, etc.)—equal to 0.85 *(own estimate)*.
- The median global emissions per page view of 0.6 g *(own estimate)*.

In detail, this calculation involves two preliminary steps, consisting of estimating energy consumption per visit (E) and subsequently calculating emissions related to each visit (C) in green hosting (C_{GH}) and no green hosting (C_{NGH}).

$$E = (GB/V \times 0.81[kWh/GB] \times 0.75) + (GB/V \times 0.81[kWh/GB] \times 0.25 \times 0.7) \quad (2)$$

where GB is the total amount of data transferred during a page view (in GB) and V is the number of visits or views.

$$\begin{aligned} C_{GH} &= E \times 442[g/kWh] \times 0.85 \\ C_{NGH} &= E \times 442[g/kWh] \end{aligned} \quad (3)$$

After this process, the Green Web Meter software computes the final "carbon footprint mitigation score" (expressed as a percentage) by comparing the product of (C) with the data on median global emissions per visit. A higher score corresponds to a lower environmental impact.

Page weight score: the "page weight score" is based on the weighted average of the total page weight per visit, considering factors such as the average share of a website's homepage visits, which account for approximately 35% of the total [20]. The result is compared with an estimated global median page weight (2.4 MB; own estimate based on the 50th percentile of total weight distribution from Web Almanac [20], calculated at 2.314 MB for websites' desktop versions). It should be noted that, the larger the amount of data required to be processed by the server, the longer it takes for the server to provide the same data to the client, consuming more electricity and thus producing more CO_2.

Green hosting: as already noted, the "green hosting" score is assigned based on the check deriving from the API call to the Green Web Data Set. A score of 100% is assigned if the website or web app is listed in the database and 0% if not.

User experience (UX) score: the "UX score" relates to the overall user experience with website pages. It is based on automated evaluations of "*Largest Contentful Paint*" and "Total Blocking Time" parameters (Core Web Vitals) through a Google Lighthouse API call. The final score is a percentage calculated by weighing individual factors (0.9 and 0.1, respectively). It is worth noting that these checks provide information about loading speed, which is relevant in terms of environmental impact. In fact, it seems necessary to specify that two pages with the same page weight can have different loading times due to the fact that the loading of some resources can be delayed by adopting different practices (such as caching or lazy loading). This delay can affect the loading and rendering processes—as it involves reducing simultaneous requests to the server—by improving speed and lessening the electricity consumption as a consequence.

4.2. Social Score (S): Social Criterion Assessment and Evaluation

The social score is calculated using the following model:

$$SC = (A \times 0.35) + (SM \times 0.20) + (SEO \times 0.20) + (BP \times 0.25) \times 100 \quad (4)$$

where SC is the social score (%), A is the accessibility score, SM is the social media, SEO is the SEO score, and BP is the best practice score.

Accessibility score: the "accessibility score" is entirely automated. It involves an API call to Lighthouse, which conducts various accessibility checks on the web pages and calculates a final weighted average based on the impact levels assigned by the Web Content Accessibility Guidelines (as indicated on the Google service's dedicated page).

Social media presence: the "social media" item examines the presence of links to the most popular platforms (e.g., Facebook, Instagram, Twitter, LinkedIn, and YouTube). Through a screening conducted with proprietary algorithms, a score of 1 is obtained if at least one link is found on the website or web app and 0 if none are present.

SEO score and best practice score: in a similar way to the "social media" score's attribution, the "SEO score" and "best practice score" are assigned directly upon completion of Google Lighthouse checks called by the Green Web Meter software. The calculation (also automated) results in a simple average.

4.3. Governance Score (G): Governance Criterion Assessment and Evaluation

The model for evaluating the governance criterion is as follows:

$$\begin{aligned} G = {} & [(Https \times 0.80) + (MC \times 0.10) + (UCO \times 0.10) \times 0.50] + \\ & +(VT \times 0.30) + (EP \times 0.10) + (PSV \times 0.10) \times 100 \end{aligned} \quad (5)$$

where G is the Governance Score, MC is the mixed content, UCO is the unsafe cross-origin links, VT is the visitor tracking, EP is the email privacy, and PSV is the public server visibility.

Basic security parameters: for the indicators "Https encryption," "Mixed content," and "Unsafe cross-origin links", the calculation logic is twofold. Through the monitoring operations conducted with proprietary algorithms, the software assigns 1 point if the screened website adopts the HTTPS protocol, or 0 if the connection is not encrypted via TLS (Transport Layer Security). Conversely, for "mixed content" and "unsafe cross-origin links", 1 point is assigned if the vulnerabilities in question are not detected, while no point is assigned if present.

Visitor tracking: the "visitor tracking" score attribution follows the same 1-0 logic, applied after the related detection through a Lighthouse API call. A value of 1 is returned if at least one tracking system is detected, and 0 otherwise.

Email privacy and public server visibility: in a similar way to "mixed content" and "unsafe cross-origin links" score attribution, the "email privacy" and "public server visibility" items (tracked through a proprietary algorithm) are assigned a value of 0 if a problem is detected and 1 if not.

5. Discussion and Conclusions

As a conclusive summary for this work, we would like to underline once more that we structured the Green Web Meter as a tool for companies and IT practitioners willing to invest in improving the digital sustainability of websites and web apps. To this end, we realised a software that is able to accomplish the following:

- Provide snapshots of ESG performances, as highlighted in (Figure 3), which features the environmental criterion evaluation dashboard;
- Support companies with actionable insights for improving the website or web app's quality and sustainability, with complete and accessible reports, which include specific and customised suggestions for implementing modifications (Figure 4);

- Assist the management operations in a complex and fast-evolving context by helping professionals to cope with the increasing regulatory constraints in sustainability compliance and reporting (e.g., CSRD);
- Reward sustainable websites and raise awareness among end-users through the issuance of NFT badges—tracked on the Arbitrum blockchain—capable of providing feedback about the compliance with the main digital sustainability guidelines, such as the UNI PdR 147 standard.

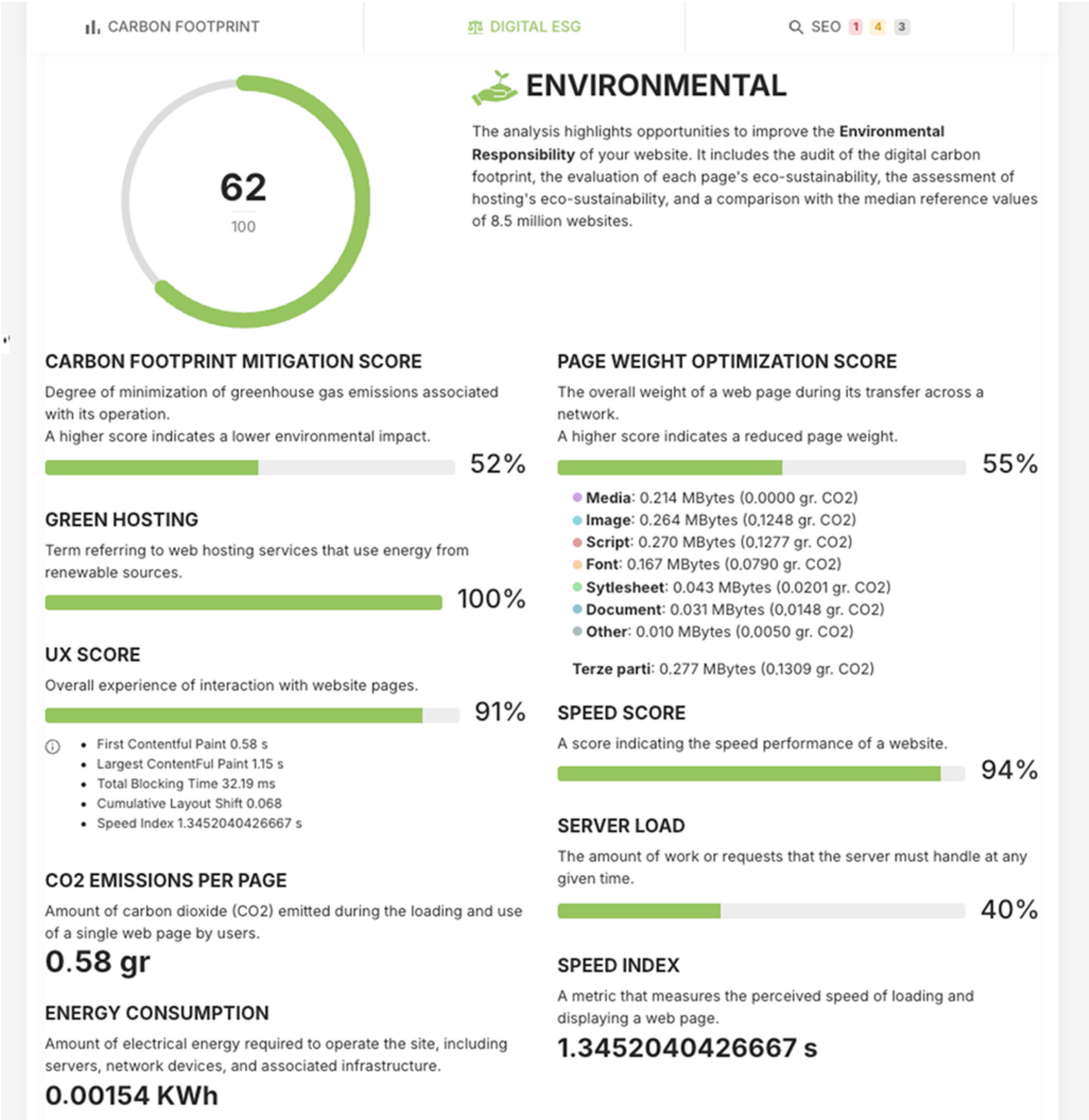

Figure 3. Green Web Meter. An environmental performance report. *Modified and adapted from: www.greenwebmeter.com (accessed on 5 July 2024).*

CARBON FOOTPRINT | DIGITAL ESG | SEO 1 4 3

Evaluation and suggestions

Assessment of the environmental impact of the website https://www.greenwebmeter.com/

As an expert in SEO and the environmental impact of digital technologies, as well as a mathematician, I have carefully evaluated the website and its environmental impact based on the absolute values of the KPIs and scores provided.

The Carbon Footprint Mitigation Score of 52.02% indicates that the site has made some efforts to reduce its environmental impact, but there is still room for improvement. The Page Weight Optimization Score of 54.76% suggests that the website could benefit from further optimization to reduce its page weight.

The MBytes transferred per pageview is 2.10 MB, which is slightly below the global median of 2.4 MB, indicating a relatively efficient data transfer. The emissions of CO2 per pageview are 0.58 grams, also below the global median of 0.6 grams, showing a relatively low carbon footprint.

The energy consumption per pageview is 0.0015 KWh, which is lower than the global median of 0.0019 KWh, indicating a relatively efficient energy usage. However, the number of server requests is 92, higher than the global median of 76, suggesting a potentially excessive server load.

Based on these values, I would recommend the following specific suggestions for improving the website's performance and environmental impact:
1. Optimize images and videos to reduce page weight.
2. Minimize the use of third-party scripts and plugins to reduce server requests.
3. Implement lazy loading for images and videos to improve loading times.
4. Enable browser caching to reduce data transfer.
5. Use a content delivery network (CDN) to optimize data delivery.
6. Compress CSS and JavaScript files to reduce page weight.
7. Minimize the use of external fonts to reduce data transfer.
8. Implement efficient caching strategies to reduce server requests.
9. Optimize server-side code to improve performance.
10. Monitor and optimize server response times to reduce energy consumption.
11. Implement efficient resource loading strategies to reduce page weight.
12. Use responsive design to optimize performance on different devices.
13. Minimize the use of unnecessary tracking scripts to reduce data transfer.
14. Implement efficient code splitting techniques to reduce page weight.
15. Optimize database queries to improve server performance.
16. Minimize the use of unnecessary animations and effects to reduce page weight.
17. Implement efficient image compression techniques to reduce data transfer.
18. Monitor and optimize website performance regularly to identify areas for improvement.
19. Consider switching to a green hosting provider to further reduce environmental impact.
20. Educate website users on the importance of sustainable digital practices to promote environmental awareness.

In conclusion, while the website has made some efforts to reduce its environmental impact, there is still room for improvement in optimizing page weight, reducing server requests, and further minimizing energy consumption. By implementing the suggested recommendations, the website can enhance its performance and contribute to a more sustainable digital ecosystem.

Figure 4. Green Web Meter report. Evaluations and suggestions. *Modified and adapted from: www.greenwebmeter.com (accessed on 5 July 2024).*

To ensure robustness and resiliency, we adopted a series of measures that include the following:

- the adherence to the OWASP security standards;
- the platform's backing on Digital Ocean servers certified with SOC 2 (Type II) and SOC 3 (Type II) certifications, granting cloud infrastructure reliance on recognised information security control frameworks;
- modular development practices with the related possibility to integrate new APIs and screening mechanisms, such as Google's Page Speed Insights as an alternative to Google Lighthouse for detecting parameters like Core Web Vitals, Accessibility, SEO practices, and so on;
- the continuous monitoring of the Green Web Meter screening data and scientific contributions to the digital sustainability topic for eventual updates as we hold that the data we used as a starting point for calculating the scores, i.e., the average global carbon intensity and median page weight, are subject to variations in time as the web technologies and electricity consumption patterns—just to mention a few—evolve.

- specifically, for the sake of providing even more accurate information to the Green Web Meter's end-users and overcoming the limitations due to the adoption of cross-country references, we plan to adapt the carbon footprint calculation to the specific regional energy's carbon intensity factor. For example, retracing the website's (or web app's) ccTLD—which is an Internet top-level domain generally used or reserved for a specific country, such as .eu, .it, .de, .fr, .es, and so on—and combining it with the related regional carbon intensity data, the Green Web Meter would be able to produce even more relevant results.

Author Contributions: Conceptualisation, A.S. and A.R.; methodology, A.R.; software, A.R.; validation, A.S., L.B. and A.R.; formal analysis, L.B. and A.R.; investigation, A.S., L.B. and A.R.; resources, A.R.; data curation, L.B. and A.R.; writing—original draft preparation, A.S. and L.B.; writing—review and editing, A.R.; visualisation, A.S.; supervision, A.S. and A.R.; project administration, A.R.; funding acquisition, A.R. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Not applicable; the study did not involve humans.

Data Availability Statement: No datasets were generated during the study, although the Green Web Meter research and development team has stored data about the more than 500 websites and web apps screened (around 20,000 webpages). The information is not publicly available for privacy reasons but is available from the corresponding author upon reasonable request.

Conflicts of Interest: Author Lorenzo Barbetti and Andrea Rosini were employed by the company Differens Srl. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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