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Developer Education for Sustainable Web Development: Evidence from the Balkan Region

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INTRODUCTION & AIM

Sustainable web development focuses on designing web pages that minimize their environmental impact by reducing digital carbon emissions while maintaining optimal website performance and user experience.
This study emphasizes the necessity of adopting sustainable web development practices in the Balkan region, highlighting the role of institutional education and web developers in encouraging environmentally responsible web practices within a Technology-Enhanced Education context.

METHOD

DATA COLLECTION

Domain data was collected using the public platform crt.sh (crt.sh, 2024), which relies on certificate transparency archives (Certificate Transparency Logs) to store SSL/TLS certificates issued for publicly verifiable domains.
All active domains were tested using the Green Web Foundation API (The Green Web Foundation, 2024).

INCLUSION AND VALIDITY CRITERIA

This analysis focused exclusively on domains that met the following criteria: they had an active DNS record, received valid responses from the Green Web Foundation API, were unique (no duplicates), and belonged to the selected country code top-level domains (ccTLDs) of .al, .mk, .rs, .me, and gr.

DATA PROCESSING AND ANALYSIS

First, three summary indicators were calculated for each ccTLD: the total number of active domains, the number of "green" domains, and the percentage of "green hosting".
A regional analysis was conducted using Matplotlib to generate visualization charts. A sectoral comparison was performed, calculating the percentage of "green" sites for each sector and country.

RESULTS & DISCUSSION

The country with the highest percentage of green domains is Greece (64.07%), while Albania has the lowest, at less than 1%. Table 1 describes, for each country, the number of domains downloaded, the number of green domains, and the percentage of green domains.

Table 1: Regional Comparison

ccTLD	Domains number	Green	Green %
gr	2858	1831	64.07%
rs	4602	1511	32.83%
me	388	83	21.39%
mk	973	194	19.94%
al	155	1	0.65%

The green hosting results by ccTLDs are also presented in Figure 1.

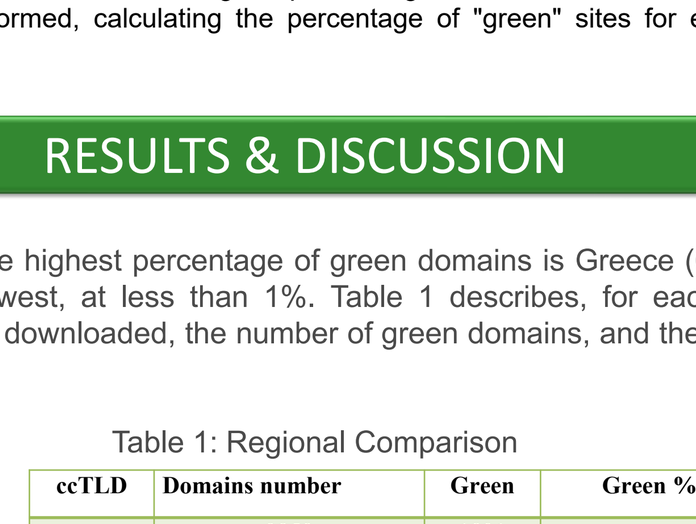

Figure 1: Green Hosting by ccTLD (%)

The most advanced sectors in adopting "green" practices are the educational sectors (.edu) and non-profit organizations (.org), while public administrations (.gov) and the commercial sector in small markets are lagging (Table 2).

Table 2: Sectoral Comparison

Sector	.al	.gr	.me	.mk	.rs
gov	13.33%	48.32%	1.79%	11.11%	14.12%
edu	0.00%	64.91%	22.64%	11.54%	34.52%
com	40.00%	73.36%	0.00%	18.91%	0.00%
org	0.00%	63.95%	28.30%	10.00%	34.99%
net	0.00%	63.52%	7.14%	0.00%	0.00%
other	14.75%	0.00%	0.00%	22.00%	0.00%

CONCLUSION

- Educational institutions and non-profit organizations are generally more receptive to innovation. In contrast, local governments and businesses tend to be slower in adapting to changes, often due to the absence of "green" policies or existing contracts that are outdated.
- These results indicate that the public sector needs new policies for digital sustainability. It is essential to increase awareness in the private sector about the economic and environmental advantages of green hosting.
- These findings reveal significant gaps in knowledge and practices among developers and institutions, indicating an urgent need for targeted educational interventions.
- Crucially, this study connects empirical evidence directly to education. Recognized knowledge gaps guide curriculum development and the design of practical training modules to equip developers and institutional personnel with the skills to adopt sustainable web practices.
- This research establishes a regional comparative baseline and offers practical recommendations for incorporating sustainability into web development education.
- The findings endorse strategies and policies aimed at promoting environmentally sustainable digital infrastructure in the Balkan area.

FUTURE WORK

- This study has some limitations regarding data sources. Not all active domains have public SSL certificates on *crt.sh*, which may lead to an underestimation of the sample size.
- Additionally, service providers that are genuinely "green" but not included in the database may be inaccurately classified as "not green."
- Future studies will examine how education and awareness can contribute to the wider adoption of Green Web Development in the Balkans.
- Efforts will focus on understanding current knowledge gaps and identifying effective training approaches that promote sustainable digital practices among future and current ICT professionals.

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