CITIWATTS: A SECURE, OPEN-SOURCE PLATFORM FOR REGIONAL ENERGY PLANNING

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Abstract

The *citiwatts* platform, an open-source toolbox developed during the European projects *Hotmaps* and *OpenGIS* for Energy Transition (*OpenGIS4ET*), supports energy planning amid the energy transition by integrating diverse energy systems and enabling flexible, data-driven analyses. *citiwatts* combines open-source and user-uploaded private data with privacy and security measures, enhancing planning precision. Its calculation modules (CMs) model complex energy scenarios like coupling electric vehicle (EV) recharge with photovoltaics (PV), allowing users to assess strategies such as EV charging coordinated with local PV generation. A case study in Sion, Switzerland, demonstrates how the platform can be used to compare the existing EV charging infrastructure with the recharging requirements to the horizon 2050. The secure, GDPR-compliant platform enables stakeholders, like local Distribution System Operators (DSOs), to integrate proprietary data and analyse energy demands at various scales. *citiwatts* emerges as a valuable tool for sustainable energy planning, offering policymakers and planners an adaptable solution aligned with CO_2 reduction goals.

1 Introduction

Effective energy planning is essential for local authorities to meet energy and climate targets, but it faces challenges like integrating renewables, managing demand variability, and coordinating across sectors. Advanced tools are needed to optimize resources, enhance efficiency, and reduce emissions, supporting urban areas in their transition to low-carbon systems.

The *Hotmaps* platform was the result of a Horizon 2020 project running from 2016 to 2020 [1]. The open-source tool can help public authorities develop energy strategies aligned with renewable and CO_2 targets by mapping heating and cooling resources across local and national levels. As energy systems become more complex, extending *Hotmaps* is essential to integrate diverse energy sources and enhance data security, enabling more precise, flexible planning. In this sense, *citiwatts* [2] emerges, providing further Calculation Modules (CM) to tackle district heating and cooling, sector coupling and electric vehicles (EV) integration together with photovoltaics (PV) in energy planning. *citiwatts* is the result of the OpenGIS4ET ERANET project (Grant agreement 883973). The platform focuses on the 27 countries members of the European Union (EU) as well as on the UK and Switzerland.

Within the *OpenGIS4ET* ERANET project, user needs have been identified through workshops with energy planners and other stakeholders, and data from various case studies has been gathered while supporting and training small municipalities in developing heating planning processes.

With the aim to enable interactions with other existing platforms and tools, used in energy planning, such as EnergyPLAN [3], *citiwatts* includes new secure APIs, and ensures security of platform with a DevSecOps approach to mitigate vulnerabilities, failures, and risks. Finally, *citiwatts* follows the FAIR (findable, accessible, interoperable, and reusable) concept in the used public datasets, and includes a full GDPR compliance, while allowing some flexibility with the integration of private datasets.

In this article, we present the platform, including the data handling, the integration of DevSecOps within the platform and finally we provide a case study in the city of Sion, where the current EV charging infrastructure is compared with the recharging requirements in 2050. This case study demonstrates how *citiwatts* enables local planners to quantify the spatial mismatch between future EV charging needs and existing infrastructure, highlighting areas where public intervention will be necessary if companies do not invest in workplace charging.

2 Materials and methods

2.1 Webtool

The *citiwatts* webtool integrates an open-source toolbox to aid local, regional, and national authorities in renewable energy, heating and cooling planning, including mobility and sector coupling flexibility strategies, that are in line with the renewable energy transition and CO_2 emission targets at the national and European level. The toolbox is user-driven, developed in collaboration with ten partners from Switzerland, Austria, Denmark, and Germany, and four observers from Romania, Denmark, and Germany. The partners include four universities (HES-SO, EPFL, TU Wien, Aalborg University), four consultancy firms (PlanEnergi, e-think, Energie Agentur Steiermark, moduldrei) and the state of Hesse in Germany. The webtool operates independently of commercial software under an open-source license. It is usable with all 27 EU member states, the UK and CH through default open datasets and is easily accessible online at www.citiwatts.eu/map.

The landing page is displayed in Fig. 1; it includes three tabs for the Tools, Layers and Calculation Modules. The Tool's tab includes the selection tools and displays the amount of elements selected, the bounding box and the scale; moreover, it allows to load results or clear them. The Layers tab allows the user to explore the different datasets in all 27 EU+UK+CH member states, including heat density, cooling density, building volumes, buildings' age of construction, industrial site emissions, industrial excess heat, motorization rate, EV density, charging stations density, solar radiation, wind speed, and average CO_2 emissions of electricity, among others. All these datasets are properly documented and stored in a Gitlab repository [4]. The datasets can be easily downloaded for the whole EU countries or for different selections at different levels (e.g., NUTS 0, NUTS 1, NUTS 2, NUTS 3, LAU 2 or at the hectare level, visible at the top right corner, as well as two background maps, satellite and road). Finally, the Calculation Modules tab provides different plug-ins for demand and supply, including heat and cool density, district heating potential, demand projections, heat load profiles, district heating potential and its economic assessment, district cooling, vehicle stock, EV density, EV charging needs, and a EnergyPLAN integration to visualize and calculate results from it.

The webtool includes a documentation wiki as well as a feedback box. The webtool supports several browsers, including Chrome, Firefox, Edge and Safari. Finally, the user can create an account within the webtool to upload proprietary data.

2.2 Data handling

The *citiwatts* platform ensures compliance with GDPR by employing measures such as data anonymization and minimization during uploads. Only essential data—including browser, operating system, country, city, and IP address—is collected, contingent on users consenting to analytics cookies. These data are strictly used for analytics and are processed by Matomo, an open-source web analytics application, with no access to user data stored in Keycloak, an open-source tool for identity and access management.

Furthermore, *citiwatts* mandates explicit user consent for any data processing and enforces strict role-based access control. Notably, only authorized HES-SO members have access to the Keycloak credentials for managing email addresses and to the Matomo credentials for handling data such as IP and city information. This ensures that sensitive information remains secure. Moreover, all data is encrypted during transmission, safeguarding integrity and confidentiality throughout the process. For additional context, see Fig. 2.

Fig. 1 citiwatts *landing page.*

Regarding public datasets, a data descriptor was established to enhance transparency, reproducibility, and usability of each dataset by providing comprehensive metadata. It includes key elements such as the dataset title, author details, affiliations, and license information, along with a summary, version specifications, and usage notes to guide users, complying with the FAIR concept. Additionally, it documents materials and methods, ensuring reproducibility, and usage notes to prevent misuse. Detailed records of storage formats, acknowledgments, and standardized author contributions offer clarity and context, enabling diverse users to assess data quality, relevance, and limitations.

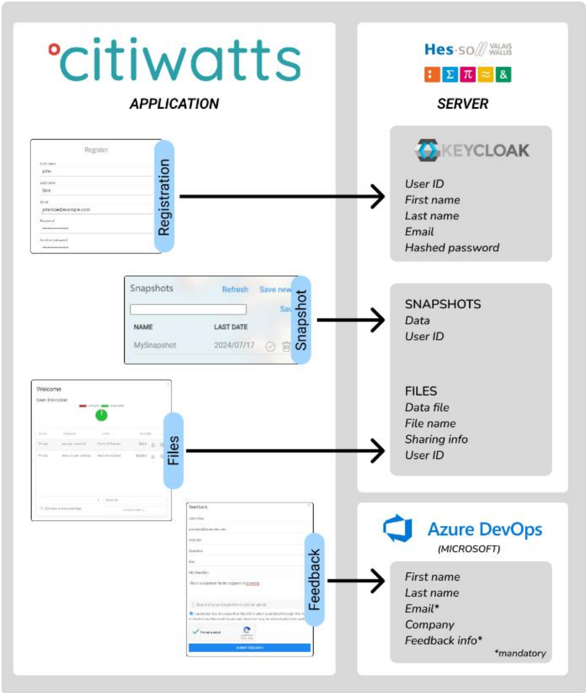

Fig. 2 Data flow of private data.

2.3 DevSecOps

Within *citiwatts*, we adopt a robust DevSecOps approach to integrate development, security, and operations, ensuring a secure, high-quality, and user-focused platform. This methodology uses automated processes and tools to embed security and quality checks throughout the software development lifecycle. Jenkins is the backbone of our continuous integration and delivery (CI/CD) pipeline, automating builds, tests, and deployments for consistent and efficient releases. We use static application security testing (SAST) to maintain code quality, catch vulnerabilities early, and manage technical debt—ensuring our codebase stays secure and maintainable.

Dynamic application security testing (DAST) helps us find vulnerabilities during runtime, while software composition analysis (SCA) and OWASP Dependency-Check protect the platform against risks from third-party dependencies. These practices follow OWASP Top 10 guidelines for addressing common security threats. By integrating these tools into our workflow, we maintain high security standards and compliance while quickly adapting to user needs. In addition, to address the operations (Ops), Grafana is employed for real-time monitoring and observability, enabling us to detect and address potential issues. Our test studio automated pipeline facilitates functional testing, ensuring the platform behaves as intended and meets user needs before deployment [5].

2.4 Calculation modules

On top of the existing modules from the *Hotmaps* platform [1], within *citiwatts*, five more CMs have been implemented. CMs within *citiwatts* we find CMs on, district heating, energy system analysis and mobility. Within district heating there are the CM on district heating potential economic assessment, and the CM on district cooling; within the energy system analysis, there is one CM integrating EnergyPLAN with the *citiwatts* platform. Finally, within the mobility section, there is the EV charging needs CM and the CM on EV density.

The district heating potential economic assessment CM allows to include reduced temperature levels at the supply and return in district heating networks, since lower temperatures allow the integration of renewable energy sources (e.g. shallow geothermal boreholes) and excess heat (e.g. from data centres) at the district level to the district heating systems, and impact technical (e.g. losses at networks) and economics (e.g. pipe dimensions) of the district heating. The district cooling CM allows to identify potential district cooling areas, and its economic viability at pre-feasibility levels is determined.

The EnergyPLAN CM allows the user to plan sector coupling strategies and load and modify input files to be passed to EnergyPLAN, as well as customize basic and advanced input within *citiwatts* and run the simulation and get the results without needing to install EnergyPLAN.

Finally, CMs include flexibility quantification from EV-PV coupling by modelling European mobility habits to estimate and spatially distribute charging demand [6], as well as modelling and comparing EV charging needs across Europe, accounting for regional mobility habits, and place of charging [7]. The EV density CM enable to estimate the number of electric vehicles per hectare for a given year until 2050. The CM is based on the population density, the motorization rate and parameters defining the electrification of the fleet.

3 Case study

This study focuses on comparing the existing charging infrastructure with the projected charging needs for 2050 in Sion, Switzerland, using it as a case study utilizing the EV-PV coupling CM, it is worth to highlight that in this case we do not use the PV output, but focus exclusively on the EV charging needs. Two scenarios, "Comfort" and "Flexible", are explored to evaluate the spatial and temporal distribution of charging demands. The aim is to assess how well the current infrastructure aligns with future requirements and to identify areas where additional infrastructure might be needed.

The input data includes the GHS population layer [8] (population projection for 2030, the further projection available for the whole Europe at the given resolution) and the current production version of *citiwatts*. The results are provided for the assumptions of the "Comfort" and "Flexible" scenarios of the Recharge au Point program [9]. Charging station data is sourced from je-recharge-mon-auto.ch, with data from 2023 [10].

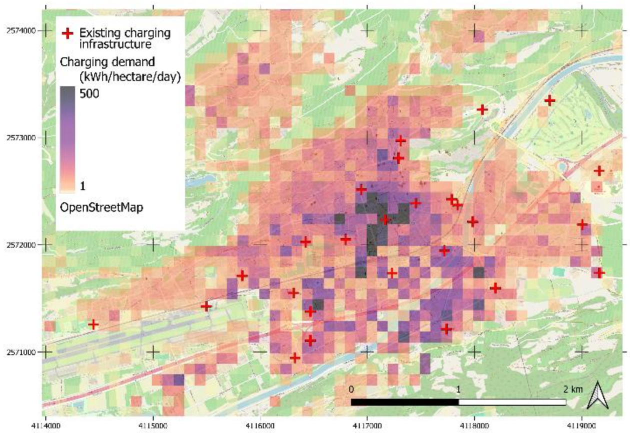

Fig. 3 Results of the scenario "Comfort".

By 2050, assuming a custom motorization rate of 0.56 vehicles per inhabitant, no modifications to account for urban-rural population density differences, a fleet yearly renewal rate of 6%, and starting with 6% electric vehicle share in 2020 and 10% of new car registrations being electric in 2020, the total number of electric vehicles is projected to reach 944,835, representing 100% of the fleet (i.e. a fully electric vehicle fleet). This figure represents 100% of the vehicle fleet by 2050, indicating a fully electric vehicle fleet by that year. It is important to highlight that we do not consider smart charging at home for this case study.

The results indicate that the "Flexible" scenario shows a much higher concentration of charging activity in industrial areas and the city centre (see Fig. 3) than the "Comfort" scenario (see Fig. 4). However, there are currently few charging stations in industrial zones. If companies do not decide to install private charging infrastructure, additional public charging stations will be necessary to meet demand in these areas.

In the "Flexible" scenario, the weekday charging need at home decreases significantly from 3.4 GWh/day in the "Comfort" scenario to 2.5 GWh/day, while the workplace charging need increases from 0.7 GWh/day to 1.4 GWh/day. Charging at points of interest also rises from 1.3 GWh/day to 1.5 GWh/day, yet the total weekday charging need remains similar at approximately 5.5 GWh/day for both scenarios.

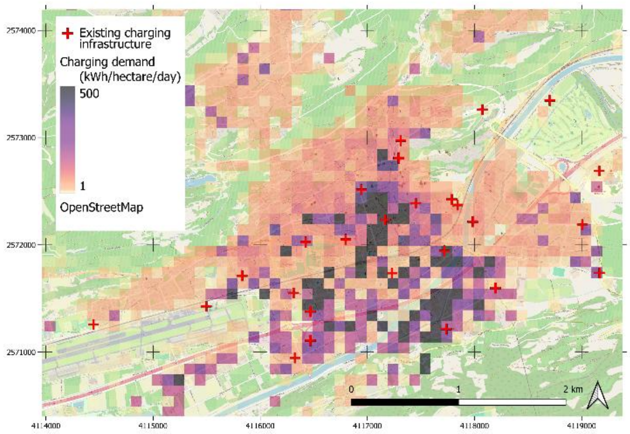

Fig. 4 Results of the scenario "Flexible".

4 Conclusions

The *citiwatts* platform contains an open-source toolbox, designed to support energy planning during the energy transition. It integrates diverse energy systems, combining open-source and user-uploaded proprietary data while ensuring GDPR compliance. The platform offers tools for flexible, data-driven analyses, enabling modelling of complex energy scenarios, such as heating and cooling density, or EV and PV coupling, and facilitating assessments like EV charging strategies coordinated with local PV generation.

Developed under the OpenGIS4ET ERANET project, *citiwatts* introduces enhanced calculation modules for district heating, flexibility, and mobility, alongside secure data handling through a DevSecOps approach. A case study in Sion, Switzerland, demonstrates its utility in comparing current EV infrastructure with future requirements for 2050. By supporting national and regional energy planning, integrating private datasets, and aligning with CO_2 reduction goals, *citiwatts* provides policymakers and planners a robust, adaptable tool for sustainable energy strategies across Europe.

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6 References

[1] ‘Hotmaps Project - The open source mapping and planning tool for heating and cooling’, Hotmaps Project. Accessed: Jan. 21, 2025. [Online]. Available: https://www.hotmaps-project.eu/
[2] ‘citiwatts - Toolbox’. Accessed: Jan. 21, 2025. [Online]. Available: https://citiwatts.eu/map
[3] H. Lund, J. Z. Thellufsen, P. A. Østergaard, P. Sorknæs, I. R. Skov, and B. V. Mathiesen, ‘EnergyPLAN – Advanced analysis of smart energy systems’, *Smart Energy*, vol. 1, p. 100007, Feb. 2021, doi: 10.1016/j.segy.2021.100007.
[4] ‘Hotmaps · GitLab’, GitLab. Accessed: Jan. 21, 2025. [Online]. Available: https://gitlab.com/hotmaps
[5] A. Penot, ‘DevSecOps on the Hotmaps Cloud Platform (Digital Ocean)’, Master thesis, HES-SO, 2021.
[6] N. Jeannin, A. Pena-Bello, C. Ballif, and N. Wyrsch, ‘Mapping the charging demand for electric vehicles in 2050 from mobility habits’, *Sustain. Energy Grids Netw.*, vol. 39, p. 101468, Sep. 2024, doi: 10.1016/j.segan.2024.101468.
[7] N. Jeannin, A. Pena-Bello, J. Dumoulin, D. Wannier, B. Christophe, and N. Wyrsch, ‘From PV to EV: Mapping the Potential for Electric Vehicle Charging with Solar Energy in Europe’, *Int. J. Sustain. Energy Plan. Manag.*, vol. 41, pp. 45–57, Jun. 2024, doi: 10.54337/ijsepm.8151.
[8] A. Carioli, M. Schiavina, S. Freire, and K. MacManus, ‘GHS-POP R2023A - GHS population grid multitemporal (1975-2030)’, May 2023, doi: 10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE.
[9] ‘Comment la Suisse rechargera-t-elle dans le futur?’ Accessed: Jan. 21, 2025. [Online]. Available: https://www.recharge-au-point.ch/fr/outils/comprendre-l-infrastructure-de-recharge-2050/
[10] ‘Maps of Switzerland - Swiss Confederation - map.geo.admin.ch’. Accessed: Jan. 21, 2025. [Online]. Available: https://map.geo.admin.ch/#/map?lang=fr&center=2660000,1190000&z=2&topic=energie&layers=ch.bfe.ladestellen-elektromobilitaet&bgLayer=ch.swisstopo.pixelkarte-grau&catalogNodes=energie,2420,2427,2480,2429,2431,2434,2436,2767,2441,3206,2419