CARBONARA

Carbon Footprint Tracker for Software Development

Schlussbericht

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Brief Description of the Task and Motivation During the Funding Phase

What was your motivation? What problem did you want to solve with your project? What was the planned approach to solving the problem (including key milestones)?

MOTIVATION

The motivation behind Carbonara was the need to **address the lack of transparency regarding the environmental impact of software development** and cloud infrastructures. Although software contributes significantly to global CO_2 emissions (holding up to 4% of global emissions, just as much as aviation does) **developers and organisations often have zero visibility and feedback on the carbon impact of their code**, and very limited ways to communicate it to their team and managers.

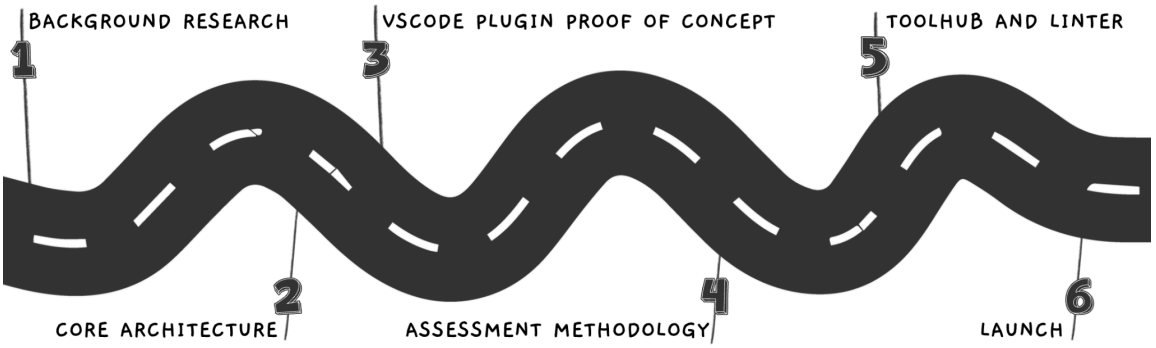
ENABLING CARBON AWARE SOFTWARE DEVELOPMENT

Carbonara aimed to add a visible level of awareness regarding CO_2 emissions, to support informed decision-making and **responsible software development**, by providing developers with the means to not only monitor their code's carbon footprint, but have **access to clear feedback and actionable recommendations** too, Carbonara allows for early emissions assessment during the development

process, within existing development workflows, being therefore set to reduce carbon emissions while software is built by providing **early measurement and practical guidance**, helping teams meet their sustainability goals from the very start.

FROM DISCOVERY TO A FUNCTIONAL PROTOTYPE

Carbonara hit the road with a discovery and planning phase, based on foundational research conducted during the first 4-6 weeks, which helped define the scope of the prototype and establish a roadmap. The planned implementation was based on a **modular architecture**, in order to develop a plugin that can be integrated into common code editors as well as CI/CD pipelines, and taking into account open-source best practices, accessibility, and community-oriented development, the roadmap focused on user research, the development of a functional prototype, integration with CI/CD systems, and a public open-source release including documentation and a demo presentation. Throughout the development of Carbonara there was continuous exchange with experts, understanding and analysis of insights from user research, to incorporate all learnings into the design and development of a modular architecture for an actual functional prototype: a code editor plugin, published on the VS Code Marketplace.



Contribution of the Project to the Goals of the "Software Sprint" Funding Initiative

What connections exist to the thematic areas of "Infrastructure" and "Security" of the Software Sprint or to other socially relevant goals or solution approaches?

Carbonara makes a direct contribution to the **Infrastructure** thematic area of the Prototype Fund's Software Sprint, particularly in the context of sustainable digital infrastructures. It focuses on development environments and addresses core infrastructural components of modern software systems.

In addition, **Carbonara contributes to socially relevant goals such as climate protection, responsible use of technology, and sustainability in the digital**

sector.

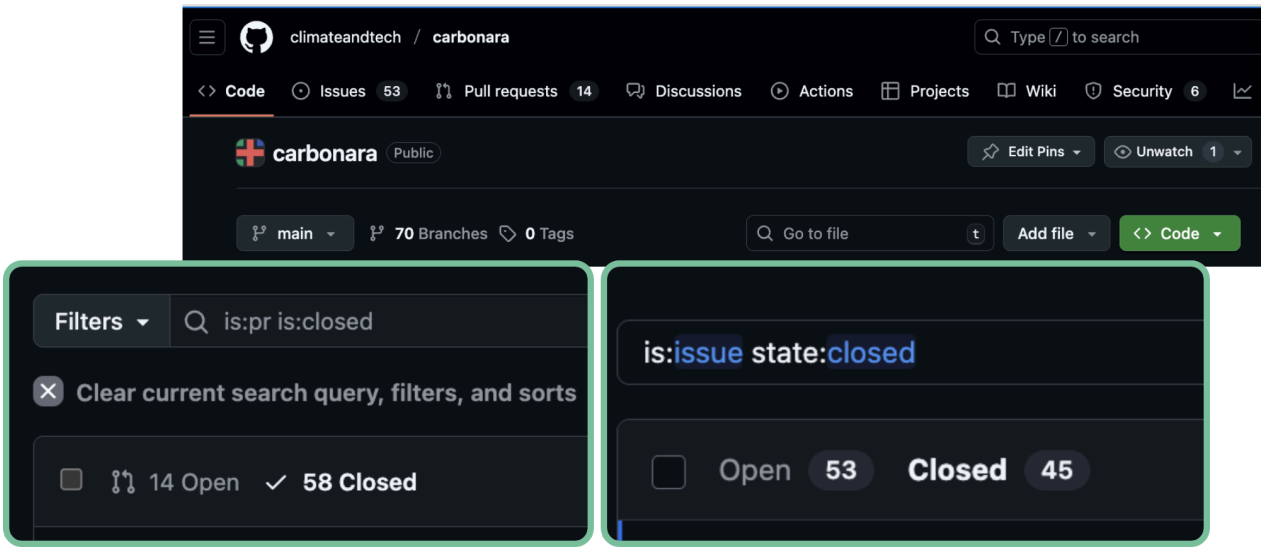
Detailed Description of the Results During the Funding Phase.

What concrete results did you achieve? Were all milestones reached? What additional insights did you gain from the project work, including in relation to the support provided by the Open Knowledge Foundation?

ACHIEVING MILESTONES AND OUTCOMES

During the funding phase, the focus was on conceptual development, architectural design and implementation. Core concepts such as CO_2 calculation based on cloud data and local development environments, integration into CI/CD pipelines, and editor-based feedback were defined and implemented in a prototypical manner.

The main milestones – **technical planning, prototype development, and preparation for release** – were achieved as planned during the funding period of Prototype Fund's 1st Stage.

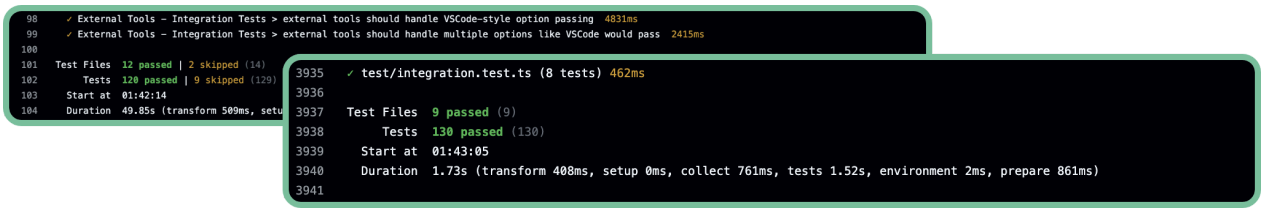


By the end of the funding period, we had reached all planned milestones, closing **45** issues and merging **58** pull requests.

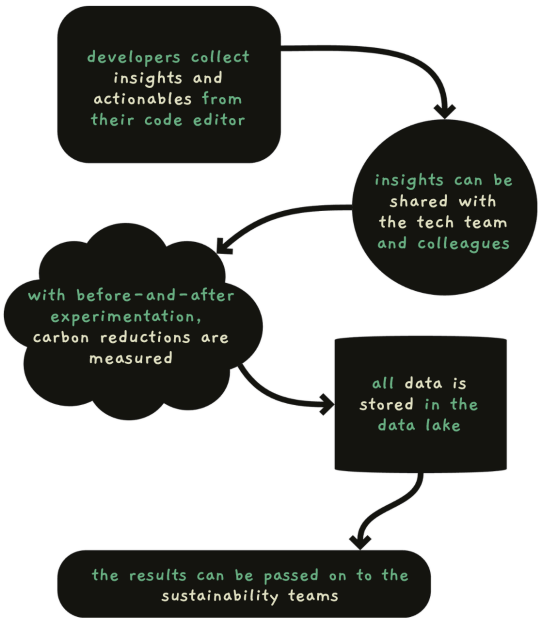
Within 6 months, Carbonara was built as an open-source plugin that gives quick, in-editor insights into the carbon emissions and energy use of code and cloud setups, to help developers understand and shrink the environmental impact of their software and empower green coding through climate-conscious decision making.

Throughout the implementation and development process, we followed a test-driven approach to ensure reliability, maintainability, and code quality. This

methodology allowed us to validate functionality early, iterate with confidence, and build Carbonara on a robust and extensible foundation.

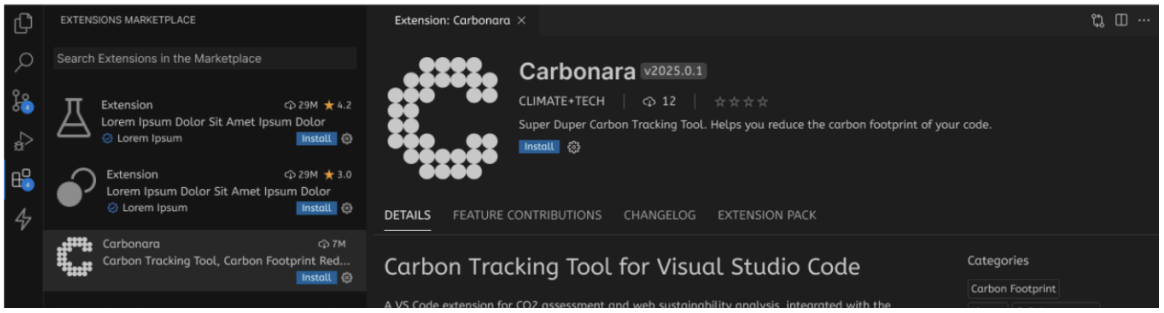


HOW IT WORKS



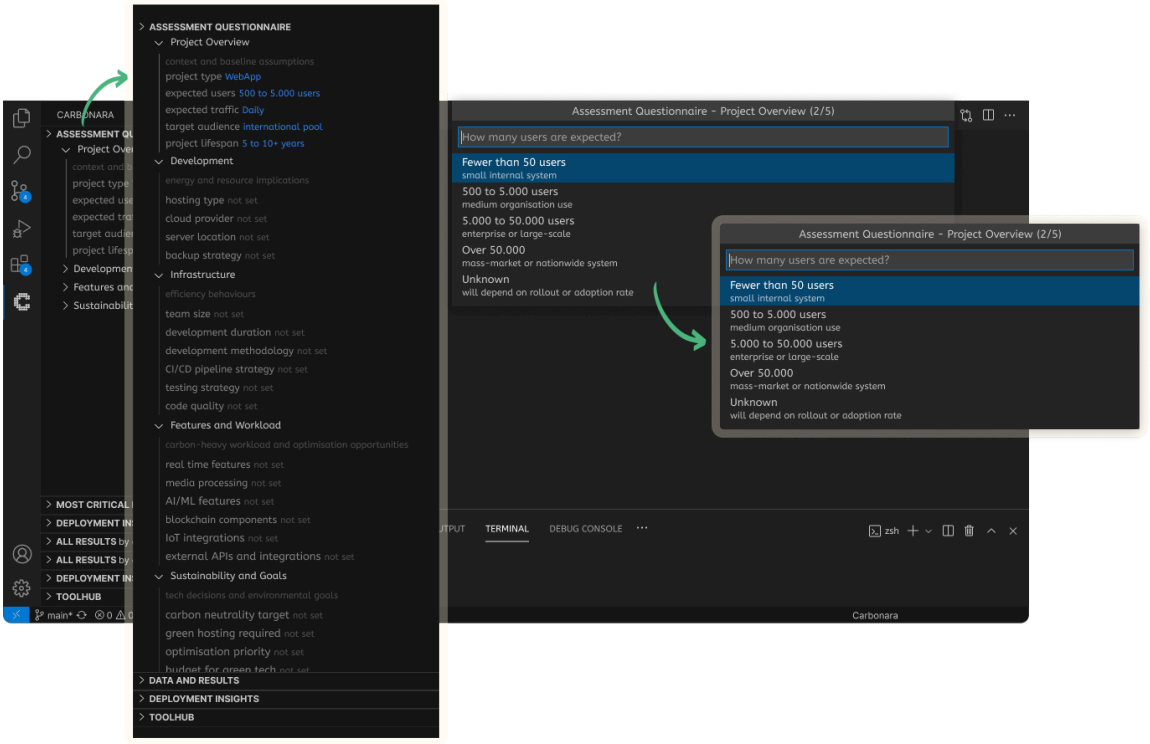
While aimed at developers first, the user journey of Carbonara is inclusive and simple. Developers start with collecting insights and actionables directly from VSCode, which they can then share with colleagues and the tech team, in order to plan adjustments to their code and decisions focusing on carbon reductions. All data is stored and presented in a comprehensive manner, making it easy to share with sustainability teams too. **Carbonara promotes a transparent and informative workflow across teams, thus** supporting sustainability goals to be met.

Carbonara is available for download in VSCode's Market Place and works through the **CLI, as well as it is easy to access from the editor's sidebar**.

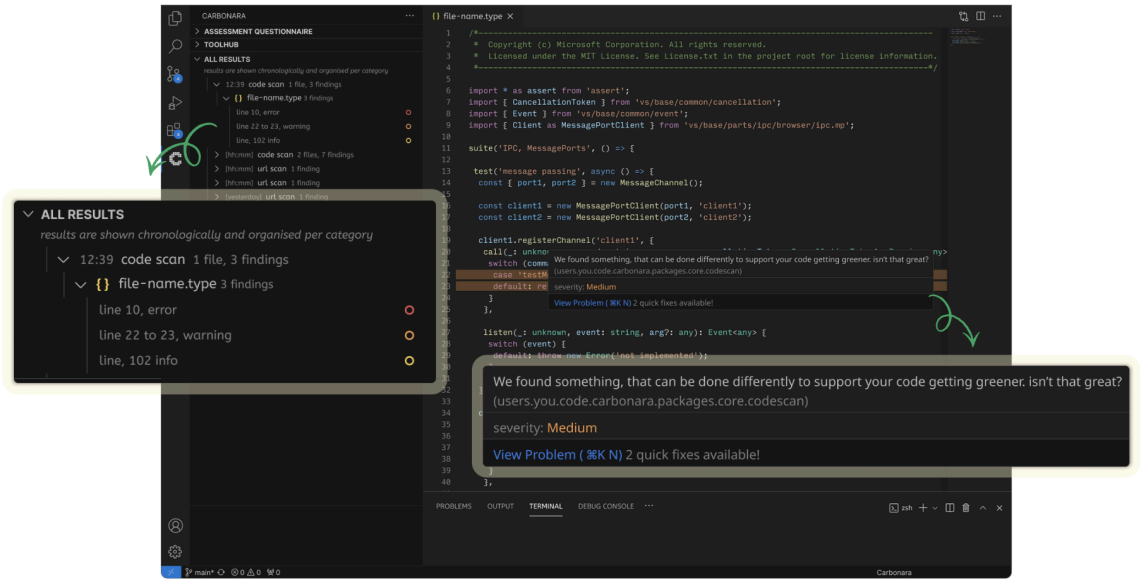


It uses linters to analyse and **highlight carbon intensive areas, and give practical suggestions.** It includes an assessment questionnaire, code scans, browser based tracking, actionables and progress tracking with data.

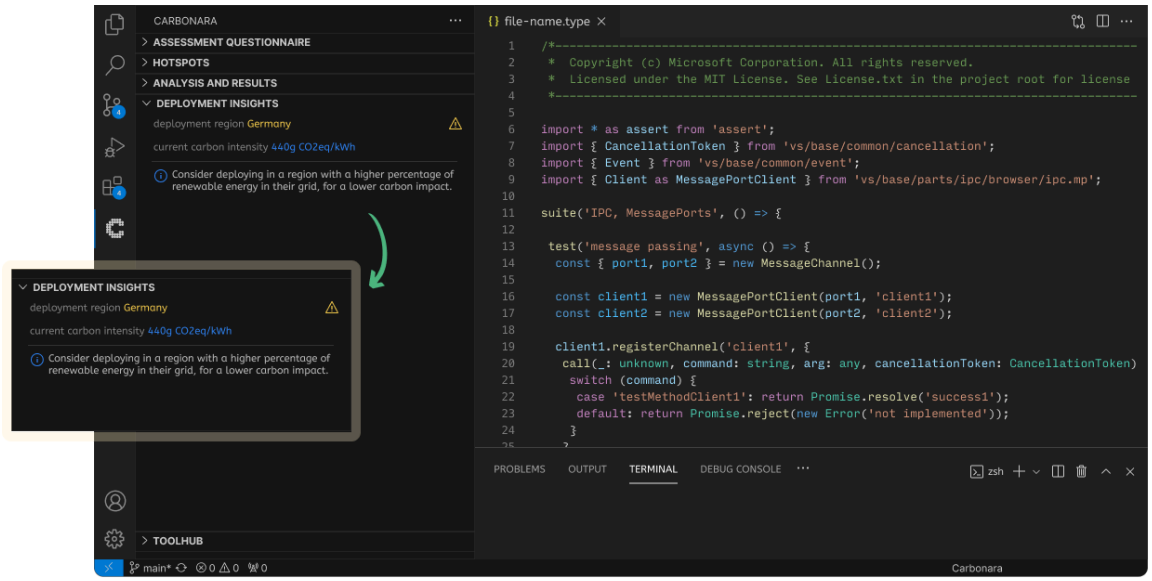
The **Assessment Questionnaire** captures information about the software project and its infrastructure to establish a baseline for carbon and energy impact, and meaningful recommendations.



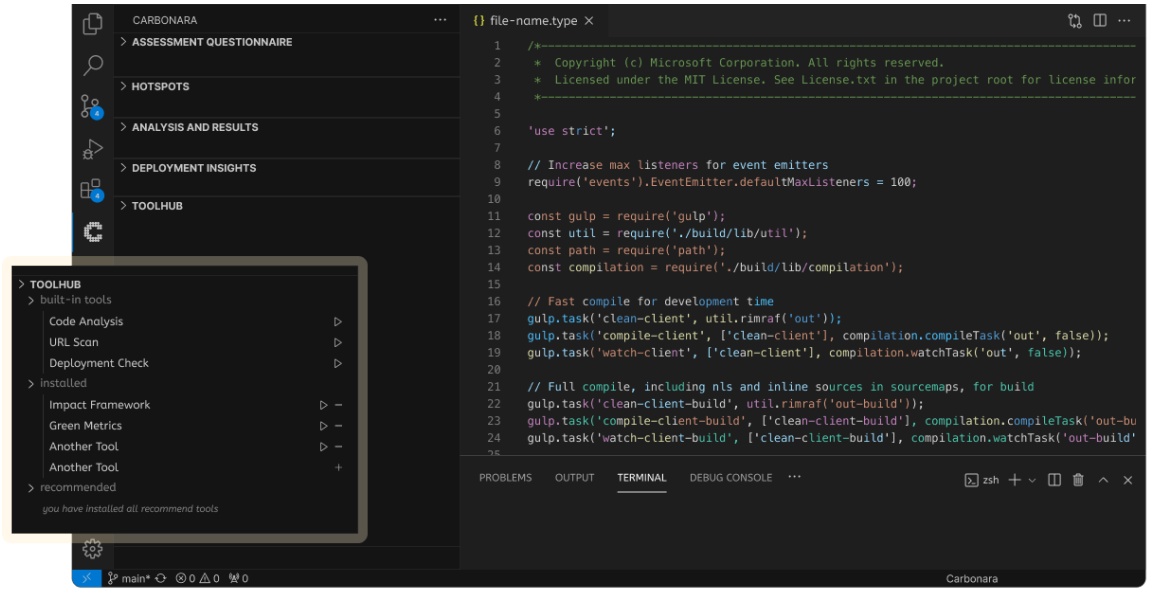
Code Scans analyse source code to identify carbon-intensive patterns, classify them in 3 levels of severity, and provide actionable suggestions for more sustainable alternatives. **Browser-based scans** measure the energy and carbon impact of web applications during real usage in the browser.



Deployment insights surface emissions and efficiency data related to hosting, cloud configuration, and supports developers and teams in adjusting their deployment choices consciously.

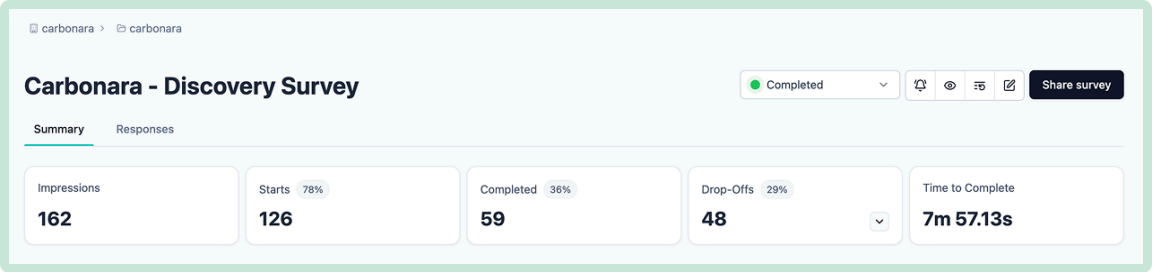


The **Toolhub** comes with a set of built-in assets and centralises recommended tools, resources, and integrations for carbon-aware development and optimisation, in a curated manner, allowing developers to discover and install state-of-the-art solutions instantly without the need for time-consuming research.



USER RESEARCH

An important insightful moment for the development of Carbonara remains on **data collected through the user research** survey, which provided **valuable information to support decision making** processes and shape Carbonara as a user-centered product.



We gathered more than 150 impressions with more than 50 fully completed forms. Users shared opinions and thoughts of where they want and expect feedback for their code, why they care for green code and carbon reduction, mentioned the code editors they use, and commented on the likelihood to integrate Carbonara within their workflows. A third of the participants showed interest in testing the tool and being contacted for a follow-up call and demo.

ADDITIONAL INSIGHTS - COMPROMISES AND COMPLEXITY AWARENESS

While during the funding period we had to pick one single code editor (VSCode, which holds the biggest slice in the market) **the necessity of a modular and extensible architecture became clear** with the need to plan Carbonara's smooth expansion to other code editors.

Furthermore, our initial research quickly pointed at the complexity of accurately estimating emissions across different infrastructures, which was a great push to connect with experts in the field, share knowledge and rethink Carbonara: we did not aim to reinvent the wheel, but connect the dots and make software's carbon footprint reduction actionable!

Target Group, Benefits, and Possible Further Developments.

What benefits do the results of your project offer to the target group? What further effects result from the open-source nature of the results? Are there ideas for further development of your solution and plans for their implementation? Did working on the project support your personal and professional development?

USER GAINS

The primary target group consists of software developers, DevOps teams, and organizations interested in sustainable software development. Carbonara supports them finding the things they can work on, with specific actionables to

assess and reduce the carbon footprint of software during development without disrupting existing workflows.

OPEN SOURCE

The open-source nature of Carbonara provides advantages such as transparency, community collaboration, adaptability to different infrastructures, and long-term sustainability.

FURTHER DEVELOPMENT

Moving beyond the funding period, we want to work further on documentation, expand to additional code editors, enhance dashboards for comprehensive understanding of data across teams, deeper CI/CD integrations, and keep up to date with emissions models precision. We want to gather additional user feedback to ensure Carbonara answers the needs of its users.
Most importantly, we plan to **establish a community and project partnerships**, following-up on existing contacts and through news ones.



PROFESSIONAL AND PERSONAL GROWTH

Working on the project supported the team's personal and professional development, particularly in the areas of sustainable technology and the specifics of building a code editor plugin, which was a task none of us had yet been challenged with. Building Carbonara also deepened the understanding of the environmental impacts of software development and emphasized the importance of responsible digital innovation.

Brief Description of Work That Did Not Lead to a Solution.

Were there approaches or solution paths that were not pursued further? What were the reasons, and how did you proceed alternatively?

In an early phase of the project, before specific technical approaches had been defined, certain ideas (such as building a carbon emissions measurement model entirely from scratch) were not pursued further. This approach proved unnecessary given the availability of established and well-founded models, and it was considered insufficient because it would not have added meaningful value to Carbonara.

Instead, a modular plugin approach was adopted. This allows for flexible

adaptation and seamless integration of third-party tools, increases the credibility of Carbonara by not attempting to replace or outperform existing expert models, and explicitly embraces collaboration by working with external specialists and proven solutions.

Brief Description of Presentation Opportunities for Potential Users.

Where can interested parties find detailed information about your project results? Please include a link to the code (e.g., GitHub, GitLab), as well as any website or additional links.

Those interested in Carbonara can learn more about the project through the public open-source repository hosted on GitHub. In addition, documentation, tutorials, and presentations are available. Soon an online demo presentation of Carbonara along with its vision, functionality, an open call for contributions and specific interest on partnerships will be made available.

As of now, information on Carbonara can be found on the following links:

- https://github.com/climateandtech/carbonara
- https://climateandtech.github.io/carbonara
- https://climateandtech.com/en/research-projects/open-source-carbon-tracker-for-software-development-code-editor-plugin
- https://climateandtech.com
- https://www.prototypefund.de/en/projects/carbonara

Brief Explanation of Compliance with Work and Budget Planning.

Were there events during the project that required adjustments to the plan, such as additional or reduced effort for certain tasks?

Initially, our team consisted of four members. Due to the mandatory requirement to form a GbR when working as a team, one team member was no longer able to participate, as their place of residence and tax setup were outside Germany and therefore incompatible with the regulations for establishing a GbR.

At that stage, **adjustments were made within the intended scope of the funding period by redistributing tasks among the three remaining members**.

From that point onward, **the project followed the planned work structure and defined milestones, with no fundamental deviations from the original work plan**. Each team member worked slightly more hours than originally applied for, which was expected and undertaken voluntarily by all members.

Brief Description of Any Results Achieved by Other Parties.

Were there developments by other individuals or institutions that influenced your work and objectives? If so, what was their impact and how did you address it?

A range of organisations and individuals continuously fight for improved carbon accounting and carbon reduction in ICT.
Several of these efforts directly influenced our work and objectives, and remain an inspiration in the development of Carbonara.

To name a few:

Lene Saile, who builds highly optimised custom websites, was an important influence on throwing Carbonara on the path of carbon reductions for software.

Didi Hoffmann, from **Green Coding** and a Prototype Fund peer grantee, provided valuable insights into the inaccuracies and complexities of carbon measuring.

Steffen Müller, himself a Prototype Fund grantee too, driving sustainability at Salesforce, reinforced the importance of solutions that can integrate into existing industry workflows and influenced our focus on usability and real-world applicability.

Both **Tin Geber** and **James Vasile** from Superbloom contributed with valuable advice on topics such as business/community models and licenses, respectively, as well as facilitated connections to key initiatives in the field of software sustainability.

The **Green Software Foundation**'s ongoing work, including its compilation of tools, frameworks, and best practices, served as an important foundation for our implementation.

In parallel, the **CodeCarbon** project influenced our approach by demonstrating how carbon accounting can be embedded into modern AI and software development workflows, validating the relevance and urgency of our objectives.

Collectively, the contacts we established throughout the funding period and the insights gained from them helped us better understand the limitations of current methodologies and guided us in designing a more robust and transparent product.