Energy Consumption and CO_2 Emissions of a Software — Who is Responsible?

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Abstract

Because our climate is warming and one of the factors for climate change is CO_2 emissions, the European Commission, with its Green Deal, has set a goal for Europe to be climate neutral by the year 2050. Finland has set this goal even closer in the future by the year 2035. These tight goals mean need for reduction of CO_2 emissions in every field. This study aims to define software-based emissions and seek responsible parties for those emissions. This study was carried out as an interview study. Interviews were done on two Finnish projects related to Green ICT. 32 interviews were conducted between May 2022 and June 2023, consisting of 6 procurer interviews, and 26 producer company interviews. The analysis of the interviews was supported by the internal project meeting discussions among experts and a set of multi-stakeholder workshops. As a result, a Shared Responsibility of Software Emissions (SRoSE) framework was developed to support organizations in mapping out their software emissions and all the stakeholders linked to the software and to share the ownership and responsibility of the emissions.

Keywords

Software, CO2 Emissions, Stakeholder Responsibility, Reporting.

1. Introduction

The European Green Deal[1] aims to make Europe climate-neutral by the year 2050. The Finnish government has set an even more ambitious goal for Finland to be carbon-neutral by 2035[2]. This means a significant reduction of CO_2 emissions in every field, including information and communications technology (ICT) even though the ICT sector has significant potential of reducing emissions in other areas as Issa et al. [1] have stated. The Finnish Ministry of Transport and Communications published Climate and Environmental Strategy for the ICT Sector in March 2021 [2]. The strategy gives propositions on how to promote environmentally sustainable ways of creating digital solutions, how to use digital solutions in a more environmentally friendly way, and how to utilize the circular economy in the field of ICT. However, the strategy does not define who has the responsibility for the emissions of these services.

One way to implement the strategy has been executed in two projects related to climate and environmental sustainability in the ICT sector in Finland. The authors of this paper managed and participated in these projects. The first project is called Green Metrics for Public Digitalization Acquisitions – MitViDi[3]. The goal of the project was to produce a set of metrics to evaluate the climate and environmental impacts of individual software, with a focus on public procurements. This project is referred to as Project 1 further in this paper.

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[1] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[2] http://urn.fi/URN:ISBN:978-952-327-843-1
[3] https://tieke.fi/en/projects/green-metrics-for-public-digitalization-acquisitions-mitvidi/

The second project is the Green ICT Ecosystem -project[4] which has built an ecosystem around the topic of Green ICT in the Uusimaa region. The main objectives of this project were to bring different stakeholders together, raise awareness and knowledge of green ICT, and establish a Green ICT ecosystem. The Green ICT project is referred to as Project 2 further in this paper.

Both projects initiated a question "Who is responsible for emissions of software solutions". In this framework, we propose that the responsibility does not rest only with the owner of the software but also in the companies that produce the solution and in every company that uses the software or any other digital product or service. In this paper, we try to formulate an answer to the question *Who is responsible for the energy usage and the CO_2 emissions of software?*

2. Methods

The primary method used in this study is grounded theory [3] and the data was collected with interviews. Interviews were conducted in Project 1 and 2 with slightly different approaches between the projects. Project 1 had structured interviews whereas Project 2 interviews were more expert interviews with semi-structured models. The method of implementation was online interviews via Teams-meetings in both projects. Difference between the types of interviews is due to the purpose of interviews within Projects 1 and 2. Project 1 interviews were part of the development of the green criteria for software procurement and Project 2 interviews were part of a service design process.

In Project 1 interviews were indicated to both procurers and producers. In the early stage of the project, the main goal of the interviews was to find out the current situation in organizations, and what kind of practices there are in use to pay attention to climate and environment in software procurement and production processes. The procurer interviews aimed to have a wide enough understanding of the state on the procurer side.

Interviews in Project 2 were part of the service design process of a self-assessment tool for organizations to evaluate their level of climate and environment-neutral actions and to provide a base for their development plan. For the actual service design process five companies were selected to participate and co-design [4] the tool, and three rounds of interviews were conducted. Participated organizations are presented in Table 1 and the data collection periods in Table 2. The total amount of the interviews was 32 with 21 individual organizations.

Table 1
Identification of the organizations participated in the interviews.

Type of the organization	Identification of the organization, A = procurer, B = producer
Education	A1, A5
Public ICT organisation	A2, A3
City	A4, A6
Software	B1, B2, B13
Consult	B3, B5, B7
IT services	B4, B6, B8, B9, B10, B11, B14
Advertising agency	B12
Expertise	B15

Table 2
Collection of the interviews

Set of interviews	Participated organisations
May–Jun 2022, Project 1, procurer interviews	A1, A2, A3, A4, A5, A6
Jun 2022–Feb 2023, Project 1, producer interviews, 1st rnd	B1, B2, B3, B4, B5, B6, B7, B8, B9
Apr–Jun 2023, Project 1, producer interviews, 2nd rnd	B5, B10, B11
Oct 2022–Jan 2023, Project 2, three rounds of interviews	B5, B12, B13, B14, B15*

*participated only for the two first rounds of interviews

[4] https://tieke.fi/en/projects/green-ict-project/

3. Result

Key insights from the interviews were summarised in these three themes which led to the development of the framework:

- There is a lack of understanding about the emissions of software as a whole, partly due to the complexity of the subject.
- There is no common understanding in assigning responsibilities for the climate and environmental impacts of software or how to agree upon it
- There is a need for simple guidelines and concrete tools for defining the climate and environmental impact of software and the distribution of the responsibilities related to it.

The Shared Responsibility of Software Emissions (SRoSE) framework (figure 1) is presented for a b2b procurement situation, where software is produced for a procurer, who sets up the requirements for the software. A producer, such as a software company, is responsible for the whole software development process. After the development, the software is maintained by the procurer and used by the end users. In this paper, we use the web-based tool developed in Project 2 as an example case.

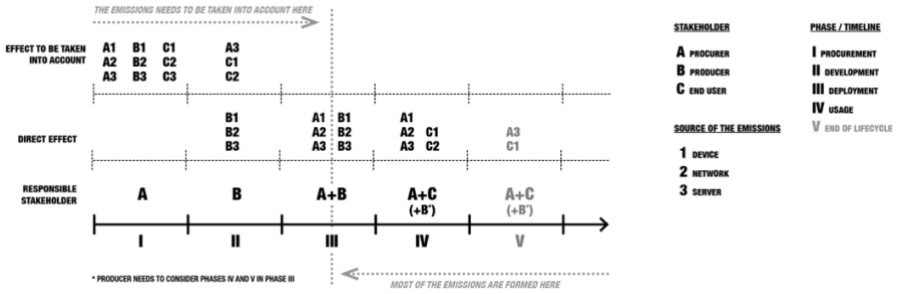

Figure 1. SRoSE framework for the shared responsibility division of the carbon emissions from software.

The framework has three stakeholders defined, three types of sources of the emissions and timeline which includes five phases. The stakeholders defined are procurers, producers and end-users. Procurers are the parties buying the software and can be public or private organizations. Producers are the parties developing the software. In practice, these are IT companies. End-user is the party using the final product. It is worth mentioning that one might have both procurer and producer roles in subcontracting chains.

The three components of the framework are device, network, and server. The device can refer to a desk computer, a laptop, a tablet, or any other hardware unit used by the end user to run the software client. Networks refer to any internet connection formed wirelessly, with Wi-Fi or mobile networks, eg. 5G, or with fixed networks. Server refers to any form of hosting platform, either physical server, virtual server, cloud server, or other cloud hosting method, such as serverless instance.

Timeline has five phases based on the life cycle of the software. The division is based on the experience in the projects, results from the interviews, and previous studies [5, 6, 7]. Procurement is the phase where the use cases and requirements for the software solution are defined by the procurer. In the public procurement process, discussion of the ownership of emissions should be addressed in the market dialogue, so that they will not become externalities. The development phase includes the design, software engineering, and testing of the software. At the end of the development phase, the software is deployed to the production environment for use by the procurer. In the usage phase, the procurer provides the software for end-users to use. This is the phase where most of the emissions occur. The end of the life cycle is also a phase that

needs to be considered when discussing emissions of software. After the lifecycle comes to an end, it needs to be discussed, what happens to all the data stored in servers.

4. Discussion

How then to calculate, measure, or evaluate the emissions? Eg. Bozelli et al. [8] in their systematic literature review on green software metrics explored the literature, so ways to measure the impacts have already been suggested. Simon et al. [9] in their recent study have presented CO_2e emissions distribution between life cycle phases of software at a more precise level than we present in this paper. So, what and how have been answered in previous studies, but they lack the question of who. That is something that we have tried to answer in our study. The sector is developing fast and regulation at the EU level is reacting to this eg. by extending the reporting with the new CSRD directive. It is expected to have recommendations and standards for the reporting soon. With the SRoSE framework, we want to help organizations be ready for the changes and new obligations. Because of the regulatory character of the reporting, it is important to have a common understanding of the division of these emissions to avoid reporting the same emissions multiple times. It is worth mentioning that even though small and medium-sized companies wouldn't be obligated to have the reports made, being in a subcontracting chain of a bigger company might bring the need for providing this information. We believe our SRoSe framework clarifies how the responsibilities should be divided, giving incentives for all the stakeholders to minimize the emissions.

5. Conclusion

As an answer to our RQ "*Who is responsible for the energy usage and the CO_2 emissions of a software?"* we argue that the responsibility should be shared between the stakeholders.

It is recognized that the framework needs to be validated and is planned to be done in the end of 2023 with some accurate software development cases and iterate the framework. It can be hypothesized that the framework will be extended by the cases and the framework will look different between different cases.

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