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A Web-Based Application for Estimating the Greenhouse Gas Emissions of Estonian Organisations

Bachelor's thesis (9 ECTS)

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Abstract:

The worldwide effort to become climate neutral means that organisations have to be more aware of their greenhouse gas emissions and calculate their greenhouse gas footprints regularly for third parties. The Estonian Ministry of Climate's emissions calculator model is an outdated solution for this problem. This thesis's intent is to modernise the model by creating a web application with a user-friendly interface and contemporary web design principles called *Rohemõõdik*, that is a modern web application built using Angular, Java, Spring Boot, and PostgreSQL.

Keywords:

Eesti organisatsioonide kasvuhoonegaaside heitkoguste hindamiseks loodud veebirakendus

Lühikokkuvõte:

Ülemaailmne püüdlus jõuda kliimaneutraalsuseni tähendab, et organisatsioonid peavad olema aina teadlikumad oma kasvuhoonegaaside heitkogustest ja regulaarselt arvutama oma kasvuhoonegaaside jalajälge kolmandatele osapooltele. Eesti Kliimaministeeriumi poolt pakutud heitkoguste arvutamise mudel on aegunud lahendus sellele probleemile. Selle bakalaureusetöö eesmärk on kaasajastada Kliimaministeeriumi mudel loodes kasutajasõbraliku liidese ja kaasaegsete veebidisaini põhimõtetega veebirakenduse nimega *Rohemõõdik*, mis on loodud kasutades Angulari, Javat, Spring Booti ja PostgreSQL'i.

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Introduction

The effort of Estonia to achieve climate neutrality by 2050 brings with it the need for organisations and companies to start evaluating their greenhouse gas footprints to avoid possible fines and embracing a more climate-friendly approach to their activities. In order to fight climate change, major sectors of the economy need to contribute to the reduction of emissions [1].

The following paragraph relies on The Carbon Trust's article on carbon footprints [2]. The need for assessing the footprint of an organisation comes down to two main reasons: reducing the organisation's emissions over time and accurately reporting the footprint to an external party. Specifically, a company that manages its footprint is a company that is well prepared for the future and assessing such footprint can be an efficient tool for energy and environmental management. Additionally, the greenhouse gas footprint of an organisation is gaining more attention, especially for investors that value achieving carbon neutrality.

This thesis aims to develop a web application, called *Rohemõõdik*, which calculates an organisation's greenhouse gas footprint by using an existing model that has been offered by the Estonian Ministry of Climate. The application fully automates the above-mentioned model, allowing users to enter data about their organisation via a user-friendly interface. Such data is then processed and used to calculate the company's greenhouse gas footprint. The application uses Estonian-centric emission factors provided by the existing model for calculations. *Rohemõõdik* aims to provide Estonian organisations the opportunity to find the impact they have on the climate and help them to understand what needs to be done to help the reduction of emissions in the atmosphere.

The rest of the thesis is structured as follows; Section 2 discusses the Greenhouse Effect with a detailed explanation of the different types of greenhouse gases as well as Estonia's and the European Union's efforts in reducing them. Section 3 gives a detailed insight into the existing model made by the Ministry of Climate and how the developed application automates it. Section 4 discusses closely relevant applications, their limitations, and how Rohemõõdik advances them. Section 5 specifies the functional and non-functional requirements for the development of the application as well as the adopted tools, frameworks, and technologies used to develop it. In Section 6, a detailed explanation of the application is given and the

results are introduced, along with possible future plans, ideas and developments for it. Finally, we conclude the thesis in Section 7.

1. Greenhouse Effect and Greenhouse Gases

In this section, background information is given about greenhouse gases, the importance of reducing them as well as the objectives of Estonia and the European Union (EU) in reducing them.

1.1 The Greenhouse Effect and the Importance of Reducing It

The following paragraph is supported by an article published by The National Aeronautics and Space Administration (NASA) [3]. According to NASA, the Greenhouse Effect occurs when heat cannot escape into the atmosphere and is, instead, absorbed by substances called greenhouse gases. Greenhouse gases radiate the heat in all directions warming the Earth in the process. There are six main greenhouse gases: carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapour. As water vapour also increases the effect of forces that initially caused the warming, it is referred to as a feedback.

The greenhouse effect has negative influences on our lives as the planet's surface temperature is increased to extreme levels. The amount of carbon dioxide in the atmosphere has risen more than 40 percent since the middle 18th century and there is a possibility that the current levels are as high as they have been in the last 14 million years [4].

According to a study by Kimmo Ruosteenoja et al. [5] thermal winter duration has been decreasing steadily in the European part of the former Soviet Union. The study also found that between 1891 and 2003, the durations of summer and winter have increased by +11 days and -29 days, respectively, in southern Estonia. The research concludes that the climate in Northern Europe is bound to change drastically in the projected future, with the average thermal summer increasing by 2 weeks at both ends and the average thermal winter shortening by 2 to 3 weeks at both ends. They state that if this pattern continues, the probability of very long summers and very early springs is increased to 60-70% while the probability of very short winters increases to 65-75%. According to the research, climate changes also impact human society and wildlife, for example, the growth of forests is likely to accelerate. However, this is cancelled out by the increasing risk of forest fires. The analysis states that there is a possibility that if the global climate policy succeeds, the projected changes to the climate could be weaker. However, according to a report by the World

Meteorological Organization, 2023 was the warmest year on record, with the average temperature of the Earth at 1,45 ± 0,12 °C above the pre-industrial average [6].

1.2 Global Warming Potential

According to Eurostat, the global warming potential (GWP) is a measure to assess how much of an impact a greenhouse gas will have on atmospheric warming over a period of time [7]. It is used to determine the effect that each particular greenhouse gas will have on climate change as well as differentiate gases from one-another based on the GWP. Carbon dioxide (CO_2) is used as the baseline for GWP, as it has the lowest warming potential. The Intergovernmental Panel on Climate Change (IPCC) gives out a new assessment report (AR) every six to seven years, in which it updates the GWP of emission factors [8]. Table 1 shows information about the GWP of four of the main greenhouse gases used in the Estonian Ministry of Climate's model.

Table 1. Global warming potential of greenhouse gases. [6]

Greenhouse gas	Global warming potential AR4 (2007)	Global warming potential AR5 (2013)	Global warming potential AR6 (2021)
Carbon dioxide	1	1	1
Methane	25	28	27,9
Nitrogen dioxide	298	265	273
Nitrogen trifluoride	17200	16100	17400
Sulphur hexafluoride	22800	23500	25200

The assessment reports are used in the Estonian model as the basis for determining emission factors and calculating organisations' GHG footprints [8].

1.3 Greenhouse Gas Protocol

The Estonian Ministry of Climate's model is based on the universal Greenhouse Gas Protocol: a Corporate Accounting and Reporting Standard (GHG Protocol) [8]. The Greenhouse Gas Protocol home page [9] states that their mission is to establish global standard frameworks for measuring and managing greenhouse gas (GHG) emissions in private and public sector operations, value chains, and mitigation actions. Currently, they aim to create new standards, tools, and online training to help countries and cities monitor progress towards climate goals. Their website describes that the Protocol is widely used by companies and cities around the world, in 2016, 92% of Fortune 500 companies used the GHG Protocol, either directly or indirectly.

1.4 Efforts Undertaken by the European Union and Estonia to Fight Climate Change

The Estonian Ministry of Climate is currently working on a draft for a climate law that could be enacted as soon as the first of January 2025. If enacted, the law would affect Estonian organisations in all sectors, including enterprises in the energy, industrial, transport, construction, agricultural, and forestry sectors [10]. While the exact details of the law are still under debate, it is more than likely that organisations in Estonia have to be more aware of their GHG footprint in the future and carry out calculations of it at regular intervals.

The following paragraph is supported by an article made by the Council of the European Union [11]. The European Union has set climate objectives for the years 2030 and 2050, with the final goal of obtaining climate neutrality by the year 2050. Climate neutrality means obtaining a net-zero emissions balance, where the amount of greenhouse gas released into the atmosphere is neutralised. There are many different ways of achieving this, including utilising a process known as carbon sequestration, that is removing carbon from the atmosphere, or supporting climate oriented projects.

In accordance with the European Union's goal of obtaining climate neutrality by the year 2050, Estonia has established its own 2050 objectives. According to a law passed by the Estonian government, Estonia has to be climate-neutral by the year 2050, with the aim of reducing adverse effects of greenhouse gases and taking advantage of the positive ones [12].

The law does not rule out using tax policy to influence the sectors of the economy to make more climate-friendly decisions, if it is purposeful, cost-effective, and economically justified.

There are already many systems and requirements in place in the European Union for organisations in relation to achieving climate neutrality goals by 2050. One of the main ones that is already being used actively is the EU Emissions Trading System (EU ETS) [13]. EU ETS's main goal is to reduce GHG emissions by taxing companies and organisations that pollute more than the maximum cap set by the System and generate revenue to finance more green projects. The cap is being reduced annually in accordance with the EU's climate objectives [13]. Another measure used by the European Union to urge organisations to use a more climate-friendly approach to their activities is regulation for the environmental, social and governance (ESG) rating activities. According to the European Commission [14], the ratings give companies the means to evaluate their investments and provide more sustainable financial products. They state that ESG ratings are becoming more crucial for the everyday operation of capital markets and bringing in investor trust.

2. Analysis of the Existing Model

This section introduces the existing model of the Ministry of Climate, how it works, and what its main shortcomings are.

2.1 Brief Introduction

The Ministry of Climate's model [15] is a computational model made in a spreadsheet and developed by the Stockholm Environment Institute's Tallinn Center. The model is aimed at enabling Estonian organisations to determine their greenhouse gas (GHG) footprint. It is accessible to organisations from the public, private, and non-profit sectors and downloadable at their website: https://kliimaministeerium.ee/media/11597/download. The model is universal, but may require user customization, including the addition of specific activities and emission sources. It is based on international GHG footprint calculation standards, primarily the Greenhouse Gas Protocol, but has been adapted to account for Estonia-specific assumptions and conditions. Although the model is designed to be broadly usable, there is a possibility that organisations will need to customise it according to their own needs and add activities and emission sources.

In this model [16], seven main greenhouse gases are used to calculate the GHG footprint: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). To maintain the universality of the model, it encompasses emission sources or activity categories within three main scopes. Scope 1 (M1) covers emissions arising from the organisation's own activities. Scope 2 (M2) consists of emissions resulting from the consumption of energy purchased from other organisations. Scope 3 (M3) encompasses emissions from transportation, travel, home offices, investments, and other sources. Additionally, the model includes Estonia-specific emission factors, mainly based on data from Estonia's GHG inventory and other foundational data. Users are advised to use the default specific emission factors provided in the model, as the ministry plans to regularly review and update these factors in the future. The calculations of GHG are based on the data from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

2.2 Using the Model

Initially, the user must enter mandatory information about their organisation into the model, including defining the scope of the organisation (departments, units) and the time period for which the GHG footprint is to be calculated. Users can also enter the number of employees and other general data. Activities and emission sources falling under the scopes are categorised under different tabs. Each tab provides a brief description of the principles of GHG calculation and displays calculation tables where information about the company can be entered. Upon entering data, the GHG emissions for the observed activity or emission source are calculated on the page.

The model also provides the option to fill fields from a dropdown menu in several cases. Information mainly needs to be entered in numerical form. In addition to the results displayed on the tabs, a separate page shows the model's aggregate results, where one can view the entire GHG footprint of the organisation, the footprint per employee, or other indicators if specified. The results page is displayed in Figure 1. It is also possible to divide the organisation into units and view each unit's individual footprint. The results page also features diagrams visualising the organisation's GHG footprint both by unit and as a whole.

Figure 1. Ministry of Climate's model's results sheet [16].

The model's specific emission factors are derived from the latest publicly available data, which are added on a separate tab in the table under references. If an organisation wishes to add its specific emission factors, there is a provision for this in the model. This is recommended for calculating the GHG footprint of activities outside Estonia, and if the user

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has more accurate and activity-specific emission factors. In such cases, a reference to the original source of the other specific emission factor would also be expected.

The author believes that the functionality of the table is well-thought-out and comprehensive. Its data are up-to-date and have been updated annually since 2021. However, one of the main shortcomings of the model is its bulkiness and complexity. Although descriptions on how to fill in the fields are provided on the introductory page and the tabs, this could be done much more compactly. Figure 2 demonstrates the GHG footprint energy calculation sheet for M1 scope.

Figure 2. Ministry of Climate's model's M1 energy GHG calculation sheet [16].

The table also lacks a filtering option by tabs, as this is not supported by the Microsoft Excel (Microsoft Office Professional 2016) software. As such, all 31 tabs of the model are always available for the user. The sheer amount of tabs in the model is certainly not user-friendly, and while many of them are essential for the model, some exist for the sole purpose of storing information about the emission factors, as is shown in Figure 3, and extra information about the model.

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Kütuse-/energialiik	tC/TJ	CH4 kg/TJ	N2O kg/TJ	kg CO2 ekv/GJ	Eriheitetegur tabelisse	Ühik	Andmeallikas
ERIHEITED (AR5)							
Sisukord							
HT - Energia (M1, M2)							
M1 - SOOJUS- JA ELEKTRIENERGIA TOOTMINE							
Biomass (nt puiduhake, saepuru) (kg)	0.00	0.97	0.70	0.212	0.00076	kg CO2 ekv/kg	KHG inventuuri aruanne 2023, kütteväärtus 11,9 MJ/kg
Biomass (nt puiduhake, saepuru) (kWh)	0.0000	0.29	0.21	0.064	0.00023	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Biometaan (kWh)	0.00	0.00	0.12	0.032	0.00011	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Biometaan (m³)	0.00	0.02	1.13	0.300	0.00108	kg CO2 ekv/m3	KHG inventuuri aruanne 2023, katlad 1-50MW, 2021. a maagaasi keskm
Diisel (kWh)	19.98	3.00	0.60	73.519	0.265	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Diisel (l)	198.12	29.74	5.95	728.864	2.624	kg CO2 ekv/l	KHG inventuuri aruanne 2023, kütteväärtus ~35,69 MJ/l
Freesturvas (kWh)	28.90	1.72	2.45	106.665	0.384	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Geotermaalenergia (kWh)	0.00	0.00	0.00	0.000	0.000	kg CO2 ekv/kWh	CoM 2017
Hüdroenergia (kWh)	0.00	0.00	0.00	0.000	0.000	kg CO2 ekv/kWh	CoM 2017
Kerge kütteõli (kg)	238.15	0.04	2.04	873.772	3.146	kg CO2 ekv/kg	KHG inventuuri aruanne 2023, kütteväärtus 42,5 MJ/kg
Kerge kütteõli (kWh)	20.17	0.00	0.17	74.014	0.266	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Kivisüsi (kg)	178.37	6.93	10.39	656.974	2.365	kg CO2 ekv/kg	KHG inventuuri aruanne 2023, 2021. a kivisöe kütteväärtus 24,94 MJ/k
Kivisüsi (kWh)	25.75	1.00	1.50	94.832	0.341	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Maagaas (kWh)	15.07	0.00	0.12	55.288	0.199	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Maagaas (m³)	142.41	0.02	1.13	522.475	1.881	kg CO2 ekv/m3	KHG inventuuri aruanne 2023, katlad 1-50MW, 2021. a maagaasi keskm
Olmejäätmed (kWh)	13.91	0.00	0.13	51.033	0.184	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023 (fossiilne)
Põlevkivi (kWh)	27.82	0.00	0.82	102.238	0.368	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi generaatorgaas (Kiviõli) (kWh)	44.92	1.00	0.10	164.755	0.593	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi poolkoksigaas (VKG Petr III) (kWh)	19.30	1.00	0.10	70.821	0.255	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi generaatorgaas (VKG) (kWh)	48.15	1.00	0.10	176.595	0.636	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi poolkoksigaas (Enefit 280) (kWh)	19.66	1.00	0.10	72.133	0.260	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi poolkoksigaas (Kiviõli) (kWh)	19.69	1.00	0.10	72.238	0.260	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi poolkoksigaas (VKG Petr I) (kWh)	18.08	1.00	0.10	66.348	0.239	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkivi poolkoksigaas (VKG Petr II) (kWh)	18.83	1.00	0.10	69.098	0.249	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023
Põlevkiviõli kerge fraktsioon (kg)	237.35	0.04	2.03	870.823	3.135	kg CO2 ekv/kg	KHG inventuuri aruanne 2023, kütteväärtus 42,3 MJ/kg
Põlevkiviõli kerge fraktsioon (kWh)	20.20	0.00	0.17	74.113	0.267	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Põlevkiviõli raske fraktsioon (kg)	229.87	0.04	1.88	843.367	3.036	kg CO2 ekv/kg	KHG inventuuri aruanne 2023, kütteväärtus 39,22 MJ/kg
Põlevkiviõli raske fraktsioon (kWh)	21.10	0.00	0.17	77.413	0.279	kg CO2 ekv/kWh	KHG inventuuri aruanne 2023, katlad 1-50MW
Päikeseenergia (kWh)	0.00	0.00	0.00	0.000	0.000	kg CO2 ekv/kWh	CoM 2017

Figure 3. Ministry of Climate's model's emission factors sheet [16].

The size of the table also initially prevented the author from opening it on their computer, as there were too many tabs. The model also displays an extensive amount of information for the users, and while some of it is useful, it would have been better to move some of these texts into a separate document.

2.3 Shortcomings of the Existing Model

The Climate Ministry's model is not perfect, and its bulkiness and complexity make it difficult for organisations to use. The main shortcomings of the table stem from its software, Microsoft Excel, which looks outdated and is not very user-friendly. A web application would have a much more modern appearance and would be easier to use by implementing modern features of development platforms. One of the main shortcomings, which is the size of the table, could be addressed in the web application by using only one page to display data. The application would allow users to filter specific fields or scopes as desired. Additionally, the website would visually display the entered data, providing users with a good overview of the organisation's GHG footprint. Furthermore, the application would be usable on mobile devices, giving organisations the ability to calculate their footprint away from their computers. The website would also provide the option to save a draft of their data.

3. Analysis of Related Applications

Various applications exist on the internet that calculate organisations' greenhouse gas footprints. This thesis covers two of the most prominent of such applications: Carbon Footprint Ltd. calculators and SME Climate Hub Business Carbon Calculator.

3.1 Carbon Footprint Ltd. Calculators

Carbon Footprint Ltd. is a company based in the United Kingdom, whose goal is to track and reduce carbon emissions and compensate for unavoidable emissions with carbon offsetting [17]. They have many carbon emissions calculators for different groups, including a GHG footprint calculator for individuals and different calculators for organisations. This thesis will focus on the different business calculators.

Carbon Footprint Ltd. has two business calculators available to use. The first one is the organisation's old business carbon footprint calculator. The user must start by entering the country of origin for the organisation, the number of employees, and optionally the calculation period. After that, data must be entered about the building, flights, and different vehicle emissions about the organisation. The entered data is then calculated and the results are shown under the "Results" page. Figure 4 demonstrates this calculator.

Figure 4. Carbon Footprint's old business emissions calculator [18].

The author of this thesis believes that this calculator is outdated and not particularly user-friendly. It can be a good choice when the organisation is not large in scale and the precision of the organisation's carbon footprint is not as important as getting a general overview of the company's emissions. It is also difficult for organisations in Estonia to use it as the Estonian language is not supported by the calculator and the calculator's emissions factors are not Estonian-centric, which means that the results would be different if the Ministry of Climate's model was used instead. However, this calculator is outdated and will no longer be actively supported after 2024 [18].

Instead, Carbon Footprint encourages users to use their new Sustrax Lite business emissions calculators. There are different versions of Sustrax Lite to choose from:
- Sustrax Lite regular, which is free to users but also has many limitations in place of what is supported in the calculator;
- Sustrax Lite X, which supports more features than the regular version but still has some limitations;
- Sustrax Lite XL, which supports all the features that are required to calculate a small organisation's emissions according to Carbon Footprint;
- Sustrax MX, which is meant for large businesses for calculating their carbon footprints on a large scale [18].

While the regular version is free to use, the latter three versions all require yearly payments of up to 1000 pounds per year for organisations. Figure 5 demonstrates the Sustrax Lite free calculator.
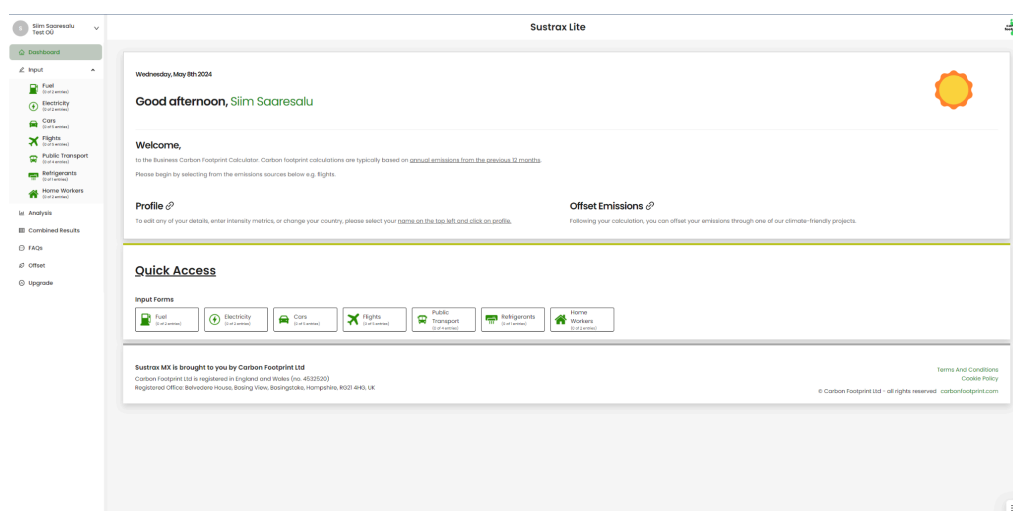

Figure 5. Carbon Footprint's new Sustrax Lite business emissions calculator [18].

In the author's opinion, the Sustrax calculator's interface is much more modern and user-friendly than the old calculator. However, because many of the features are locked behind a paywall, many smaller organisations would probably preferably not resort to paying a yearly fee for a calculator, if a more modern and free-of-charge calculator exists. Although the application says it supports the Estonian language, the translation did not work, instead the application threw an error. The application's interface is also quite cluttered, so it may be hard for new users to find the features they are looking for. Because the calculator is international, it is not Estonian-centric, meaning that the emission factors are different from the Ministry of Climate's factors.

3.2 SME Climate Hub Business Carbon Calculator

SME Climate Hub's Business Carbon Calculator is a free carbon emissions calculator for small and medium-sized enterprises (SMEs) whose objective is to estimate a company's footprint and reduce its emissions [19]. The application uses the Greenhouse Gas Protocol for calculations and estimates the emissions in M1, M2, and M3 scopes. Initially, the user must enter information about the company, including the number of employees, the period in which to calculate the emissions, and the company's name. After that, data about the revenue of the organisation and the different emission sources must be entered. Finally, the results are displayed in the dashboard. Figure 6 demonstrates SME Climate Hub's Business Carbon Calculator.

Figure 6. SME Climate Hub's Business Carbon Calculator [19]

The thesis's author believes that while this calculator's user interface is modern-looking and is quite easy to navigate, there are some essential features missing in it that would make it a viable choice for an Estonian company. For example, the application supports only three languages currently: German, Swedish, and English. The emission factors are also not Estonian-centric and instead often use averages for calculations [21].

4. Application Requirements

This section covers the different requirements of the application, which were determined before development, focusing on improving the existing Estonian Ministry of Climate's model.

4.1 Functional Requirements (FR)

FR1: The system must support the addition of a new organisation.

This is a core requirement of the application, as it is the first step of the calculation process. Without essential data about the organisation, including the name and the reporting period, the application will not work.

FR2: The application must support both Estonian and English languages.

One of the main shortcomings of the original model is the lack of English translations. This application aims to support them.

FR3: The application must have a navigation bar.

In order to provide easy access and quick navigation between pages for the user, a navigation bar is required.

FR4: The application supports adding many entries of an emission source for the organisation

The system must support adding many entries of an organisation's emissions source.

FR5: The system must calculate the emissions of a company.

This is the most important part of the application. The user must be able to add the required information about their company for calculating the GHG footprint. The required fields vary depending on the data being added, but usually encompass the amount of the source of emissions and the type.

FR6: The system must display the GHG footprint of the company

The results page of the application must display the total emissions of the organisation and the organisation's emissions in each specific scope in each specific field.

4.2 Non-Functional Requirements (NFR)

NFR1: The application's interface looks modern and clean.

One of the core reasons for this project. The original model's Excel sheet is outdated and has an eye-straining effect on the user. *Rohemõõdik* aims to provide the user with only essential info and a non-cluttered user interface with modern design principles.

NFR2: The application has to be simple and easy to use.

The original Excel sheet was very large and confusing for organisations who used it. The application has to be simple and user-friendly, as frustration from a difficult application means a bad user experience.

NFR3: The application has to be usable on mobile.

Modern smartphones are very capable and a lot of people rely on them for work and everyday operations. Because of this, the application should have a flexible design that makes it usable on smartphones and tables of all sizes.

4.3 Development Platforms

Rohemõõdik requires both front-end and back-end solutions for it to work. As emission factors are received from the back-end and the organisational data should also be stored, the application demands a database. For the front-end, Angular was chosen as the development platform, for the back-end, the application uses Java alongside the Spring Boot framework. PostgreSQL was chosen for the database.

Angular is a development platform and framework that is built on TypeScript whose main purpose is building single-page web applications [22]. Angular supports projects of all scales, from single-developer projects to enterprise-level applications and has a wide variety of features supported by a collection of well-integrated libraries [23]. The author of this thesis chose Angular for front-end development because of its powerful features and scalability. One other reason for the choice was because the author has experience with Angular in enterprise-level solutions. For the development, Angular 17 was chosen, as it was the latest version available at the time.

Java is a programming language first released in 1995, that is being widely used today in applications and services [24]. Spring Boot is an open-source framework that is used for creating Spring-based applications, microservices and web apps in a streamlined and modular approach [25, 26]. The author chose Java and Spring Boot for the application as they are one of the most popular development platforms for back-end in the world, and make the development process streamlined and easy. Because of their popularity, there is a lot of support and information available on the internet. The application was built with Java JDK version 21 and Spring Boot version 3.2.1.

PostgreSQL is an open-source object-relational database system that uses the SQL language and applies to it many powerful and safe features, it is widely respected for its reliability, integrity, robustness, and open-source approach [27]. The *Rohemõõdik* application uses PostgreSQL version 16.2 for its data-storing purposes.

5. The Rohemõõdik Application

This section provides an extensive overview of the application that was developed for this thesis - *Rohemõõdik*. The application's source code along with the instructions for installing it are available on GitHub:

- https://github.com/ssaaresalu/bakalaureus_app, for the front-end;
- https://github.com/ssaaresalu/bakalaureus_api, for the back-end.

5.1 Architecture of the Application

The application consists of a front-end service and a back-end service. Figure 7 describes the architecture of the *Rohemõõdik* application in a simplified form.
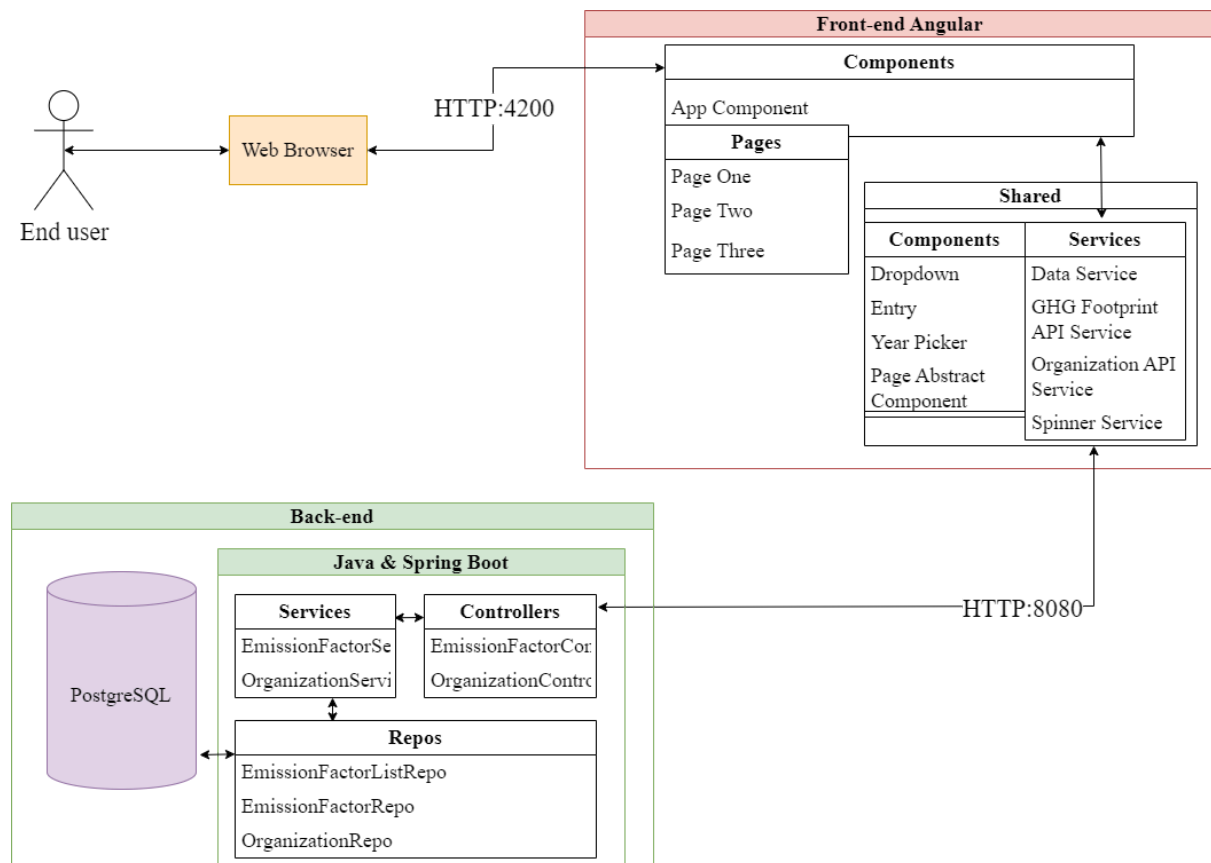
Figure 7. *Rohemõõdik* application diagram.

The front-end is built using many different components, which can be described as a hierarchy of different views that are served to the end-user via a web-browser. Components utilise services, which are used for processing or fetching data in the front-end or performing

tasks that are not directly related to a specific component [22]. In *Rohemõõdik*, services are used to communicate with the back-end application with API calls over HTTP. Data is transferred between the front-end and the back-end using JSON objects and end-points defined in the controllers. In the back-end, data is stored in and fetched from the database using Spring Boot services and repositories. Information that is being stored in the database includes data about saved organisations and emission factors used throughout the application.

5.2 Comprehensive Overview of the Application

This section will provide an extensive overview of the *Rohemõõdik* application, with explanations about each individual page, how the emissions are calculated, and how the application works.

5.2.1 Organisation Page

This is the first page that the user will interact with. On this page, information about the organisation is entered, including the name of the organisation, the reporting period and optionally info about the structural units and the number of employees per year. An introduction is given for the web application, along with a link that redirects to the Ministry of Climate's home page, where there is more information about the model. Figure 8 shows *Rohemõõdik's* organisation page.

Figure 8. Organisation page of *Rohemõõdik* (Green Measure).

The organisational info is saved and stored in the database. If the user leaves the website and returns at a later date, previously saved organisations' data is retrievable via a dropdown menu. Before the user can continue to the next page, it is vital that the organisation's

reporting period is given, as the application will not function correctly without it. Once the data about the company is entered and submitted with the "Confirm" button, the user can continue to the next page with the "Next" button.

In addition to the pages, *Rohemõõdik* also has a navigation bar for quick navigation inside the application. The navigation bar is always situated at the top of the website and indicates which page the user currently is on. *Rohemõõdik* also supports mobile devices and tables of all sizes. Its flexible design makes it easy to use from anywhere, ensuring a seamless and consistent user experience across various platforms.

5.2.2 M1 Emissions Page

The second page of the application allows users to enter data about the M1 emissions of their organisation. The data being entered is optional, meaning that the emission sources do not have to be added if the company does not have them. The data is entered on a year-by-year basis, with buttons to navigate between the years. The entries are added and shown under expansion panels, in order to avoid cluttering the user interface with too much information and for keeping it simple, as shown in Figure 9.

Figure 9. M1 emissions page for Rohemõõdik.

The user can choose which emission source is added, with a maximum of 10 entries per source type. When the user wants to remove an entry, they can do so by using the respective button for it. In order to calculate an emission source's GHG emissions, the user must enter the following data about the organisation:

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- type of the source emitted, which is required to get the specific emission factor;
- the amount of the source, which is multiplied by the emission factor;
- whether or not to use the model's emission factor, if the user chooses to instead use their own factor, they have to enter it as well;
- optionally, the unit number of the organisation which is responsible for the source.

Once the required information is added, the website automatically calculates the GHG footprint for the source. One of the most significant challenges while developing the application was keeping the data up-to-date with relevant changes. If the user makes any changes in the future about the data added, the footprint is always updated to reflect on the latest information. Once all data about M1 emissions is added, the user can click the "Submit" button to save it and can move on to the M2 emissions page.

5.2.3 M2 Emissions Page

The third page of the application allows the company to calculate its M2 emissions footprint. As with the M1 emissions page, all data entered here is optional and the calculations for the footprints have the same workflow as before. Figure 10 demonstrates the M2 page of *Rohemõõdik*.

Figure 10. M2 emissions page for *Rohemõõdik*.

Once all relevant information is entered and the data is saved with the "Confirm" button, the user can move on to the next page.

5.2.4 M3 Emissions Pages

The application divides the calculation of the company's M3 emissions into two pages: transport M3 emissions and other M3 emissions. The reason for this was because transport M3 emissions have a lot of data that can be entered and in order to preserve the simplicity and user-friendliness of the application, the choice was made to split the data. Figure 11 showcases *Rohemõõdik's* M3 transport page.

Figure 11. M3 transport page of Rohemõõdik.

The calculation of the footprint for an emission source is similar to the M1 and M2 calculation methods, although occasionally there are extra fields that the user must fill, like the capacity of the vehicle and the amount of product on the vehicle. Once all the data has been entered and after pressing "Submit", the user can move on to the next page.

The fifth page of the application consists of the M3 calculation of other items for the organisation. In this page, the organisation's data about business trips, waste, investments, purchased and sold products and many more categories is entered. Figure 12 shows the M3 other items page for the application.

Figure 12. M3 other items page of *Rohemõõdik* with financial investments open.

The data that can be entered in this page differs from others in that there are extra fields for many of the emissions categories. For example, financial investment entries have a lot of choices for the person filling in the data, and depending on the choice, content is rendered on the webpage for the user. Adding logic for this page was quite difficult, as the emissions footprint needs to be kept track of at all times and there are many conditional renderings happening that are dependent on the user, which complicate the process. Once the data has been filled, "Confirm" is clicked and the user can move on to the final page.

5.2.5 Results Page

The results page is the last page of Rohemõõdik. It displays the emissions of the company in a simple and concise way. The results are categorised into three main scopes: M1, M2, and M3 emissions. Additionally, information about each of the separate types of emissions is shown. The user can look at the emissions for different years by using the corresponding buttons "Previous year" and "Next year". The results page is displayed in Figure 13.

Figure 13. Results page of *Rohemõõdik*.

If the user wishes to update their company emissions information, they can do so by navigating back to any of the previous pages and adding or removing entries. The application keeps track of the organisation's emissions and will update the results page accordingly.

5.3 Validation

This section delves into the testing and validation of the application. Validation is required to determine if the application meets its functional and non-functional requirements and whether it satisfies user expectations.

5.3.1 Testing Methodology

The testing for the application was organised in several user interviews. In the three interviews, the participant has to complete several tasks determined by the investigator and answer some questions after completing said tasks. The tasks are completed in both the original Ministry of Climate's Excel sheet and Rohemõõdik. The main aim of the questions is to compare the two approaches to calculating an organisation's GHG emissions and establish which one the interviewee prefers. The investigator also keeps track of how much time it takes for the users to complete the tasks in both cases. Testing also gives the investigator valuable feedback about the application and helps discover any potential user issues that arise during the completion of the tasks.

During the investigation, participants filled in data about the organisation, added 2-3 entries for each of the three scopes of emissions and analysed the results. Participants for the investigation were chosen from the potential target audience for the application, including an analyst from a logistics company, whose main goal is determining the organisation's GHG footprint. The author contacted the Ministry of Climate to participate in the testing, but could not manage to include representatives from their side, as their work computers prohibit downloading software that is required to run the application.

The exact testing sheet with interview questions is included in Appendix 1. The consent form, which each of the participants had to agree to, is included in Appendix 2.

5.3.2 Results from User Interviews

The participants agreed that the original Ministry of Climate's model looks cluttered and outdated, which also makes it more difficult to use. One of the participants noted that the original Excel sheet has too much information included in some of the sheets, which also makes them exceptionally large in size and complexity. Another participant had problems with viewing the results of the organisation's emissions in the Ministry's model, as the formulas used for calculations did not work properly.

On average, the participants rated the addition of a new organisation in the original model 6.33 out of 10 and the calculation of emissions 5 out of 10. For *Rohemõõdik*, the participants rated on average the addition of a new organisation 8.06 out of 10 and the calculation of emissions 8.37 out of 10. The overall score given to the original Ministry of Climate's model was 4.66 out of 10 and for *Rohemõõdik* 8.5 out of 10. The results indicate that the participants prefer *Rohemõõdik* to the original model by a large margin.

The participants agreed that *Rohemõõdik's* design and structure are considerably better and more user-friendly than the Ministry of Climate's Excel sheet. The addition of a new organisation was more concise as there was not as much distracting information as in the original model. One of the participants noted that the year range for the reporting period should be greater than it currently is, with which the author agrees. Another participant said that the amount of employees for the organisation should be specified that it must be the annual average number of employees. Regarding the calculation of emissions for the organisation, the participants agreed that *Rohemõõdik's* approach was more straightforward

and user-friendly than the original model's. However, one participant remarked that the sources of the emission factors should definitely be included in the application, as they are an important part of the calculation and verification process. The author agrees that this change should be implemented in the future. They also noted that the unit of measurement should always be included with the input.

The investigator also kept track of the time that the participants took on completing the tasks in both the original Excel sheet as well as *Rohemõõdik*. On average, participants took twice as long to fill in the data in the original model compared to the web application. This reinforces the idea that *Rohemõõdik* is the more effective solution for users, especially with respect to time.

The participants agreed that the results of the organisation's emissions were displayed in a much more concise manner than the original sheet. One participant noticed that the company's total carbon emissions should be separated from the other results, to make sure it stands out more. Another one remarked that it would be nice to include some graphs about the emissions on the results page. The author agrees that this should be implemented in the future. Overall, all participants of the interview preferred *Rohemõõdik* over the original model.

5.4 Limitations and Possible Future Developments

There are several features and elements that were left out of the application due to the time and size limit of the thesis. Incorporating these features would have made the project too big and are therefore subject to future development. For example, *Rohemõõdik* was initially supposed to include graphs on its results page, similar to how graphs were displayed in the original model. The application also does not display the results data in regards to units and the number of employees, which was initially supposed to be added. Another limitation of the application is that the dropdown lists do not have translations added to them for the English language. The items displayed for the dropdown menus are often very scientific in nature and require precise translations, which the author of the thesis does not have.

Another major feature that was left out was a user account system for the application, which would have linked the added organisations to specific user profiles. The system could have

also included Google's reCAPTCHA system, which would have made the application more safe and abuse-free from bots or robots.

Interview participants noted that the results page should also include the source of data for the emission factors that are used, as there could be discrepancies between the organisation's and the Ministry of Climate's provided data. Adding these sources would allow users to verify whether or not the data is correct and up-to-date. It was also stated that the application could have more information added to the pages about the data being added, in a way that does not impact the simplicity of the design.

One of the participants remarked that the application could be used in the future for cross-checking information about an organisation's GHG emissions. The organisation would provide the application emission data that they have gathered along with their own calculated footprint, *Rohemõõdik* would then compare the entered data with the average for the same emissions. In case of any discrepancies, the application would have the organisation explain what methodologies were used for the calculations.

Conclusion

Due to the increasing demand for organisations and institutions to regularly provide their greenhouse gas footprint data for third parties, there is a need for an application that calculates it. This thesis aimed to enhance an existing emission calculation Excel sheet model provided by the Estonian Ministry of Climate by creating a new web application called *Rohemõõdik*, which applies modern web design principles and solutions. The application allows organisations to measure their GHG footprint and make informed decisions based on it.

Before development began on the application, research was done on the importance of reducing the greenhouse gas footprint globally. Similar applications to the one developed for this thesis were analysed for any potential features that could be incorporated into *Rohemõõdik*. The original model by the Ministry of Climate was examined extensively to determine what its main shortcomings are. The developed application calculates an organisation's GHG footprint using a simple form and displays the results in a concise manner.

The developed solution was successful in its objective. In testing, the participants preferred *Rohemõõdik* to the original model by a large margin. The users stated that the web application looked modern and user-friendly while also retaining its emission calculation functionality. The positive reception validates the thesis's effort to develop a better way for Estonian organisations to calculate their greenhouse gas footprint.

References

[1] Euroopa Liidu kliimaeesmärgid, 2022.

https://kliimaministeerium.ee/euroopa-liidu-kliimaeesmargid (14.04.2024).

[2] The Carbon Trust. Carbon footprinting: An introduction for organisations, 2007.

https://semspub.epa.gov/work/09/1142510.pdf (15.04.2024)

[3] What is the greenhouse effect?, 2024.

https://science.nasa.gov/climate-change/faq/what-is-the-greenhouse-effect/ (15.04.2024).

[4] What is a carbon footprint?.

https://www.conservation.org/stories/what-is-a-carbon-footprint (15.04.2024).

[5] Kimmo Ruosteenoja, Tiina Markkanen, Jouni Räisänen. Thermal seasons in northern Europe in projected future climate. *Finnish Meteorological Institute*, 2019, 2-17, https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/joc.6466 (15.04.2024).

[6] State of the Global Climate 2023, World Meteorological Organization, 2024. https://library.wmo.int/viewer/68835/?offset=#page=1&viewer=picture&o=bookmark&n=0& q= (15.04.2024).

[7] Eurostat, Statistics Explained.

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Global-warming_p otential_(GWP)

[8] Harri Moora, Piret Kuldna, Kristiina Martin. KHG jalajälje hindamise juhend, *Estonian Ministry of the Environment*, 2023, 11.

https://kliimaministeerium.ee/sites/default/files/documents/2023-11/KHG%20jalaj%C3%A4l je%20hindamise%20juhend%202023.pdf (15.04.2024).

[9] Greenhouse Gas Protocol home page. https://ghgprotocol.org/about-us (03.12.2023).

[10] Kliimaseaduse kaksleht, *Estonian Ministry of the Environment*, 2023, 1-2.

https://kliimaministeerium.ee/sites/default/files/documents/2023-09/Kliimaseaduse%20kaksl eht_07.2023.pdf (15.04.2024).

[11] 5 facts about the EU's goal of climate neutrality, 2023.

https://www.consilium.europa.eu/en/5-facts-eu-climate-neutrality/ (15.04.2024).

[12] Kliimapoliitika põhialused aastani 2050 (10.02.2023). *Riigi Teataja III*.

https://www.riigiteataja.ee/akt/307042017001 (15.04.2024).

[13] What is the EU ETS?.

https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en (15.04.2024).

[14] Environmental, social and governance (ESG) ratings: Council and Parliament reach agreement, 2024.

https://www.consilium.europa.eu/en/press/press-releases/2024/02/05/environmental-social-and-governance-esg-ratings-council-and-parliament-reach-agreement/ (15.04.2024)

[15] Estonian Ministry of Climate home page, 2023.

https://kliimaministeerium.ee/organisatsioonide-khg-jalajalg (03.12.2023).

[16] Estonian Ministry of Climate model.

https://kliimaministeerium.ee/media/11597/download (03.12.2023).

[17] Carbon Footprint About Us.

https://www.carbonfootprint.com/aboutus.html (07.05.2024).

[18] Carbon Footprint Business Calculator.

https://www.carbonfootprint.com/businesscalculator.aspx?c=BusBasic&t=b (08.05.2024).

[19] SME Climate Hub home page. https://smeclimatehub.org/start-measuring/ (08.05.2024).

[20] SME Climate Hub Business Carbon Calculator dashboard.

https://businesscarboncalculator.normative.io/en/dashboard (08.05.2024).

[21] Business Carbon Calculator by Normative, 2022.

https://help.normative.io/hc/en-us/articles/4423270961297-Business-Carbon-Calculator-by-Normative (08.05.2024).

[22] Introduction to Angular concepts. https://angular.io/guide/architecture (08.05.2024).

[23] What is Angular? https://angular.io/guide/what-is-angular (08.05.2024).

[24] What is Java technology and why do I need it?

https://www.java.com/en/download/help/whatis_java.html (08.05.2024).

[25] What is Java Spring Boot?

https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-java-spring-boot (08.05.2024)

[26] Spring Boot Overview. https://spring.io/projects/spring-boot (08.05.2024).

[27] What is PostgreSQL? https://www.postgresql.org/about/ (08.05.2024).

Appendix

I.   Application Testing Sheet

Description: The purpose of the web application *Rohemõõdik* is to modernise the Ministry of Climate's greenhouse gas footprint calculation model for organisations by streamlining the data entering process and presenting the results in a concise way. The purpose of this survey is to collect feedback on the use of the application and improve the application based on it. Please complete the tasks in the Ministry of Climate's GHG footprint calculation model first and *Rohemõõdik* after that.

Application task list

The participant starts from the introductory page of the web application. No organisation is initially entered, and the participant must add a new organisation.

Task 1 - adding a new organisation. Add a new organisation to the application with a name of your choice. Add the start and end year of the reporting period for the organisation's GHG footprint. Fill in the fields that appear with the necessary data and press the "Confirm" button to confirm. After finishing, please answer the following questions:

-    On a scale of 1 to 10, how would you rate the addition of an organisation?
-    How difficult was it to add a new organisation?
-    Was something missing or confusing when adding an organisation?

Task 2 - calculating the GHG footprint of the organisation. Move to the following pages in the application according to the data you enter. Add information about the organisation in different pages. When you have finished entering the data on the page, press the "Confirm" button and move on to the next page. After finishing, please answer the following questions:

-    On a scale of 1 to 10 , how would you rate the emission calculation process?
-    Was the data adding process user-friendly in your opinion?
-    Was the data presented in a concise manner in your opinion?

Task 3 - analysis of the results. After entering all the required data, move on to the last page of the application and look at the results. Please answer the following questions:

- Were the results displayed in a clear way?
- Is there anything else that could be added to the organisation's results page?

Finishing questions about the application:

- Do you think using the application was easy and user-friendly?
- Did you experience any issues while testing the app?
- What did you like and dislike while testing the app?
- How do you rate the application on a scale of 1 to 10?

Finishing questions of the interview:

- Which application do you prefer for calculating an organisation's greenhouse gas footprint?

II.   Consent Form

Dear respondents,

I would appreciate your availability to participate in this survey for the evaluation of *Rohemõõdik*.

Purpose of the survey:

The main purpose of this survey is to evaluate the web application *Rohemõõdik* and compare it to an existing solution by the Estonian Ministry of Climate.

Voluntary participation:

Your participation in this survey is voluntary. It is up to you to decide whether or not to take part in this survey. If you decide to take part in this survey, you will be asked to check the informed consent (IC) below. After that, you are still free to withdraw at any time and without giving a reason. If you withdraw before completing the survey, your input will not be recorded.

Privacy and confidentiality statement:

Your responses will be anonymous, and all responses including any personal information will be kept strictly confidential. The survey results may be presented in scientific conferences and/or journals. This study will only present the results obtained as a whole, without revealing any of your personal information, i.e., your data will only be used in combination with the responses of others participating in the survey.

The survey will take around 20 minutes to complete.

If you have any questions regarding the survey, please contact the researcher:

Siim Saaresalu

siim.saaresalu@gmail.com

Informed consent (IC)

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I voluntarily agree to take part in this survey.

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