16.2.2021

Report: study of the environmental impact of X-Road and the possibilities of reducing it

Version 1.0 Phase 1 Public Report

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Terms and Abbreviations

Carbon dioxide equivalent[1]: Carbon dioxide equivalent (CO2eq) stands for a unit based on the global warming potential (GWP) of different greenhouse gases. The CO2eq unit measures the environmental impact of one tonne of these greenhouse gases in comparison to the impact of one tonne of CO2.

Carbon emissions: The carbon dioxide released when fossil fuels are burned.

Carbon footprint[2]: The total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.

Carbon neutral: Net zero carbon emissions by balancing emissions with removal.

Cloud computing[3]: The on-demand availability of computer system resources, especially data storage (cloud storage) and computing power, without direct active management by the user.

Device power consumption: The power consumed by a device.

Device utilization: The actual load a device handles relative to the peak load the device can handle. It is expressed as a percentage.

Electricity carbon intensity: The emission rate of the electricity generation mix which is dependent on the region.

Energy efficiency: The usage of less energy to achieve the same level of activity.

Energy rating[4]: An energy rating is simply a way of measuring and showing how energy efficient an appliance is, according to how much energy it consumes.

Equipment specifications[5]: the specifications of servers, storage equipment, and networking devices used for the analysis. This includes number of cores, processor power, storage capacity, and power draw at different utilizations.

NIIS (Nordic Institute for Interoperability Solutions) – organisation that ensure the development and strategic management of X-Road.

Power use effectiveness (PUE)[6]: is the ratio of total amount of energy used by a computer data centre facility to the energy delivered to computing equipment. PUE is the inverse of data centre infrastructure efficiency (DCIE).

[1] https://climatepolicyinfohub.eu/glossary/co2eq
[2] https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/#:~:text=A%20carbon%20footprint%20is%20the,highest%20rates%20in%20the%20world.
[3] https://ieeexplore.ieee.org/document/9044834
[4] https://www.ovoenergy.com/guides/energy-guides/a-guide-to-energy-saving-white-goods.html#:~:text=What%20is%20an%20energy%20rating,how%20much%20energy%20it%20consumes.
[5] https://www.microsoft.com/en-us/download/details.aspx?id=56950
[6] https://searchdatacenter.techtarget.com/definition/power-usage-effectiveness-PUE

Server virtualization[7]: It is a process that creates and abstracts multiple virtual instances on a single server.

X-Road[8] **-** X-Road is an open-source software and ecosystem solution that provides unified and secure data exchange between organisations. The basic idea of X-Road is that members of an ecosystem exchange data through access points (Security Servers).

X-Road Central Server[9] **or Central Server**: contains the registry of X-Road members and their Security Servers. Besides, the Central Server contains the security policy of the X-Road instance that includes a list of trusted certification authorities, a list of trusted time-stamping authorities, and configuration parameters.

X-Road governing authority[10] – authority, that sets the requirements for using X-Road and establishing the procedure for using X-Road, managing and regulating participants of X-Road.

X-Road information systems: The Information System produces and/or consumes services via X-Road and is owned by an X-Road member. For a service consumer Information System, the Security Server acts as an entry point to all the X-Road services. A service provider Information System implements a REST and/or SOAP service and makes it available over the X-Road

X-Road instance[11]**:** a legal, organizational and technical environment, enabling universal internet-based secure data exchange between the members of X-Road and limited to the participants administered by one governing authority.

X-Road member[12] – participant of X-Road entitled to exchange data/messages on X-Road.

X-Road Security Server[13] **or Security Server**: The Security Server mediates service calls and service responses between information systems.

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[7] https://searchservervirtualization.techtarget.com/definition/server-virtualization#:~:text=Server%20virtualization%20is%20a%20process,instances%20on%20a%20single%20server.&text=Server%20virtualization%20also%20masks%20server,servers%2C%20processors%20and%20operating%20systems.

[8] https://x-road.global/

[9] https://x-road.global/architecture

[10] https://www.x-tee.ee/docs/live/xroad/terms_x-road_docs.html#2-participants-of-x-road

[11] https://www.x-tee.ee/docs/live/xroad/terms_x-road_docs.html

[12] https://www.x-tee.ee/docs/live/xroad/terms_x-road_docs.html#2-participants-of-x-road

[13] https://x-road.global/architecture

Introduction

X-Road has a public commitment to become the 'most sustainable data exchange service provider in the world' and thereby align its operational model with the climate and sustainable development goals articulated under the Paris Agreement and the 2030 agenda for sustainable development (https://x-road.global/sustainability). This report supports this promise and enables the executives and users of X-Road to make informed decisions which are in line with current best practices. This approach will embed a cycle of continuous improvement via innovation and real time monitoring that can ensure efficient use of resource.

The purpose of this research is to assess the current impact on climate change due to X-Road's operations and give recommendations for best practices pertaining to sustainability that can be integrated in decision making. X-Road is an open-source software and ecosystem solution that provides unified and secure data exchange between X-Road members.

The first chapter highlights the main causes of environmental impacts by an X-Road instance and explains the use-cases that are selected for a more detailed evaluation. The key function of X-Road is secure data exchange between X-Road members through public internet. Therefore, the carbon footprint is calculated for the 1) energy consumption by the infrastructure used by members and 2) data exchange for most common X-Road use-cases in Estonia and Finland. The total amount and frequency of data exchanged across all services will give a good estimate of the carbon footprint of an X-Road instance.

Second and third chapter will be added in latter phases of the project, during Feb-May 2021. Also, we expect to add and update the information in the whole document as the study progresses. The second chapter takes a deeper look into carbon footprint evaluation for the selected use-cases and provides details about a calculator for estimating the total impact of an X-Road instance. Third chapter gives recommendations and KPIs (to NIIS, governing authorities, X-Road members) for improving sustainability in all X-Road related operations. In addition, all collected data will be provided to the client as well.

The project team is a combination of the sectoral experience provided by Gofore and academic competence that is provided by Stockholm Environment Institute Tallinn (SEI). Gofore's experts have experience with X-Road core development processes, X-Road implementations and X-Road service developments. Gofore is developing a methodology, metrics and toolkit that enables organisations to embed sustainability into everyday work and in parallel embrace Good Growth as a focus for strategy and innovation. SEI Tallinn is a leading sustainability think tank ranked #1 globally in the environmental field by Uni Penn ranking. The experts of SEI Tallinn have considerable experience in climate and energy policy scenarios, carbon footprint calculations and life-cycle impact assessments.

GOFORE

1. Environmental impacts of X-Road instance

1.1. Indirect impacts of X-Road

Our experts mapped the environmental impacts of X-Road instance. Impacts that are not caused by using X-Road's services are not in the scope of this study. It is important to note that X-Road might have positive indirect impacts on some of the subsystems. These hypotheses are explained in Table 1 below.

Table 1. Environmental impacts related to X-Road, but not caused by X-Road

Subsystem	Description	Equipment examples that require emissions measurement	Indirect impacts of X-Road
Data centres	Buildings housing servers used to carry out a large variety of functions (e.g., e-mail, financial transactions, social media, etc.) and data storage. Data centers often require air conditioning units, power supply units, and other technologies to support these computer systems. Servers within data centers can be considered as end devices, which provide services accessed via the Internet.	Servers, storage equipment, power and cooling equipment, etc, energy footprint of a Security Server and data usage	Potentially positive impact. X-Road allows access to data that remains to be distributed after the transaction. That might decrease the need for additional data centers.
IP core network	Internet Service Provider (ISP) equipment which form regional, national, and global networks. This typically includes equipment that uses Internet Protocol (IP), the principle communications protocol which allows for the routing and relaying of data across networks	IP core/metro/edge switches and routers, transmission link elements (copper, fiber optic, etc.), and supporting infrastructure for cooling, power, etc.	Potentially positive impact. X-Road works on public internet and therefore avoids the need for building secure lines.
On site networking device	Customer Premise Equipment (CPE), equipment used to access the Internet and provides a link to the user's edge device, based on the customer's premise (e.g., in the home or office building). Often used to maintain a constant on-demand connection. Home/on-site networking equipment can also form a Local Area Network (LAN)	Routers Modems etc	Irrelevant, because the access to public internet will not be set up because of X-Road
User device	Hardware needed to draw functionality from internet	Laptops, ipads, consoles etc.	Irrelevant, because X-Road is a machine-to-machine solution
Energy security infrastructure	Equipment to ensure energy supply consistency and prevent surges.	Generators, power surge hardware	Irrelevant, because X-Road Security Server does not require higher level SLA than the integrated information systems

Using X-Road paves the way for a better security with less infrastructure (e.g., data centers, IP core network etc.) – especially when X-Road is implemented together with the Once-Only Principle. In that case, X-Road is an enabler for less infrastructure that will result in reduced environmental impacts. Still, without changes in existing patterns how data is managed and stored, X-Road only causes additional infrastructure to be deployed X-Road's capability to provide high security services for data exchange on public internet makes this service quite suitable and sustainable for stakeholders.

1.2. Direct impacts of secure data transaction

Secure data transaction between two X-Road members is depicted in the following diagram:

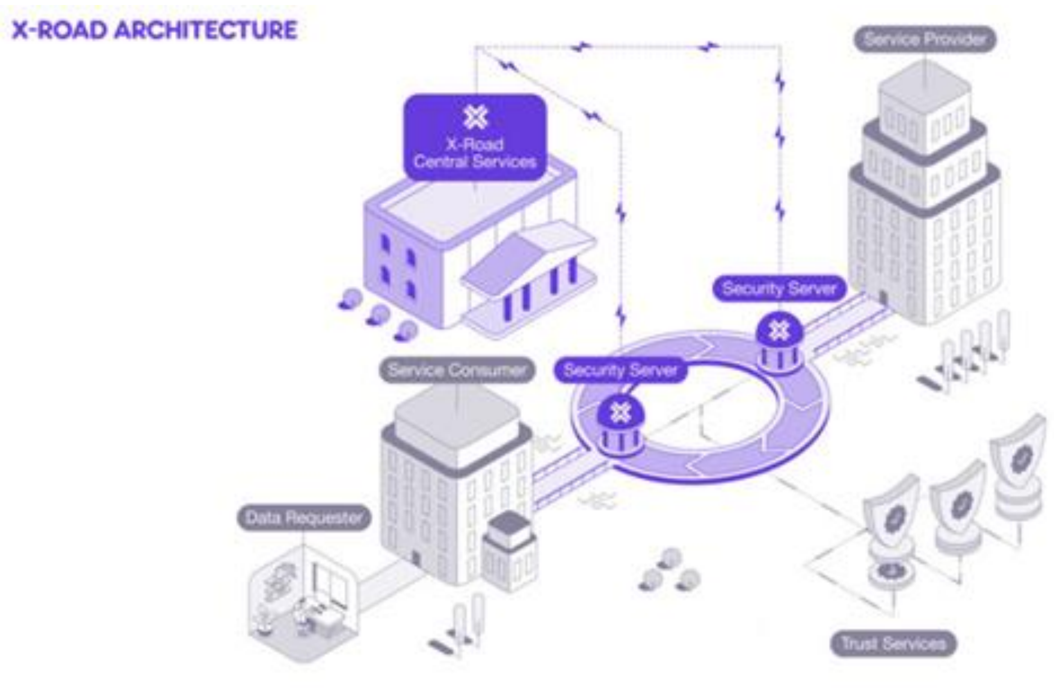

Figure 1. X-Road architecture

The main infrastructural components for secure data transaction are:

1. Central Services provided by Central Server
2. Security Servers that interact during data exchange transaction

Data exchange primarily happens between Security sSrvers of a service provider and service consumer, where different X-Road services are used. The Central Server provides the registry of X-Road members, security policy and a list of trusted certification authorities and other important parameters but however, it plays a mediating role. The certification authority issues authentication certificates which makes the data transaction secure and Information systems owned by members (consumer/provider information system) allow for consuming and producing messaging and other services. Central Server is not considered in the environment footprint calculations as its impact is quite minor. Information systems and certification authorities that provide trust services are also not included in the footprint calculations mainly because X-Road utilizes them as services while having no direct impact.

The key operation considered for environment footprint calculations is the **exchange of messages and services between two X-Road members over the Security Servers**. Relevant environmental impacts of an X-Road instance can roughly be described in the following categories:

- Life-cycle of the components used by infrastructures that allow X-Road's operations
    - Infrastructure for running a Security Server that can be on premises or in cloud.
    - Physical device that might be necessary for holding the certificates that assure the identification of the members.
- Energy consumption of the Security Server infrastructure used by X-Road members or governing authorities.

- Energy consumption in addition for exchanging messages/ using X-Road services.

The analysis of the life-cycle of different components is not a part of current study. However, recommendation for best practices will be provided. A detailed analysis of X-Road's infrastructure will pave way to indentify crucial areas where effective recommendations can be given. This will be covered in chapter 3. Environmental friendly options have to be always considered side-by-side with security requirements. The software provider (NIIS), can widen the options by building support for more use-cases. For example, in last years the support of cloud native services have been improved. At the same time, some security requirements might be set by X-Road governing authority which might result in a limited number of options for X-Road members.

1.3. Use cases for X-Road carbon footprint calculation

In order quantify and compare the impact of X-Road's operations, different use cases need to be considered. Building on the experiences of Estonia and Finland (Table 1Table 2), we plan to showcase the changes to carbon footprint caculations when change in the following parameters are considered:

- Infrastructure level
  - server used: infrastructure on-premises VS on cloud.
  - trust level: physical signing device is required.
- Service level:
  - data load/size of the message across different services.
  - message log requirements (metadata or whole message)

Table 2. Overview of X-Road reference architecture in Estonia and Finland (to be updated after expert interviews with governing authorities)

		Estonia	**Finland**
Infrastructure level	Server	On-premises: 164 Cloud: 0	On-premises: Cloud:
	Physical signing device	Was required until …	Not required
	Additional information	Recommendations	Recommendations
Service level	Average data load of the message		
	Message log requirements	Full message	Message meta-data only

The first infrastructure level use case will directly quantify and compare the emissions of X-Road's operations with physical infrastructure on premises vs when using cloud. All related emissions will be calculated, and a detailed comparison will be made in order to see the differences between impacts in both scenarios. As for the trust level scenario, the absence of a physical signing device will be compared to the presence of one.

For the second type of use case where service levels are only considered, different services will be considered with different level of data use. A map of emissions related to each service will highlight the contrast of every service in X-Road's operations. Ultimately a message log requirement is another variation of the service level that will be taken into account.

1.4. Methodology for emission models

The proposed methodology closely follows the conceptual description of CLEER, an online carbon calculator. CLEER was specifically designed for quantifying energy and emissions savings resulting from the migration of localised data services onto the cloud. The full CLEER methodology, which is published and verifiable, is composed of 13 distinct modules covering different possible sources of emission. Two of these, namely those detailing the data centre operational emissions and those associated with data transfer, have respectively been identified as the most important within the emissions boundary of the current project. It is noted that the calculation framework is independent of data centre type, ensuring that a consistent framework can be applied in all use cases. Moreover, all variables within the model come with pre-defined values that can be used as default in case of limited data variability.

Data centre operational use

As defined within CLEER there are 9 different hardware components. This includes 5 different IT types of devices (server types, HDD storage – k = 1-5) and 4 different infrastructure types (lighting, cooling, etc k= 6-9) that are considered. Infrastructure components can also be replaced by a centre wide PUE (power usage effectiveness) value. Moreover, additional hardware components of relevance can be included in the methodology as long as the average power use of the device is known.

Stage 1: determination of direct energy use by device

Within CLEER the operational energy use for a given IT device, k, within facility, j, is defined as:

$$e_{jk}= N_{jk}W_{jk}h_{jk} \qquad (1)$$

e_{jk} = Direct device energy use
N_{jk} = Number of devices
W_{jk} = average power use of device
h_{jk} = annual operating hours of device

Extension
Should the power use per device not be known, it can be estimated from the standardised database SPECpower_ssj2008. Here, the power consumption is described whilst idle (Devices such as servers also consume a non-negligible proportion of power while idle) and at full utilisation. A linear extrapolation can be performed to determine the power use at a certain utilisation (typical values are 5-10 % for a small data centre ~40 - 50 % for a large cloud vendor). The reduced power consumption associated with higher utilisation can be leveraged by reducing the number of devices included in the calculation (e.g. increasing the utilisation from 10 to 40 % would reduce the number of servers by a factor of 4).

Stage 2: Total energy use by data centre

The sum of device energy use is then multiplied by the infrastructure energy use as defined below for a single data centre, or server closet:

$$E_{operations,\, j}=\left(1+ \sum_{=69} e_{jk}\right)\left(\sum_{k=15} e_{1jk}\right)=PUE\left(\sum_{k=15} e_{jk}\right) \qquad (2)$$

The first term in brackets is the PUE. This defines the ratio of electricity required by the data centre to the amount used by the relevant IT devices. Values can range between ~2.5 for a single server (e.g. only 40 % of electricity is actually used by the IT equipment) to ~1.1 for large cloud based data centres (Google average 1.09).

The carbon emissions are determined by multiplying the energy for the data centre, Ej, by a location-specific emissions factor Gj to determine the annual emissions.

Stage 3: Conversion to carbon emissions in tonnes of CO_2e (CO_2 equivalent)

$$Emissions_{operations,\, j} = E_j G_j \qquad (3)$$

The emissions per instance are then determined by dividing the annual emissions by the number of instances per year.

Network systems operational energy use

Given the complexity involved in calculating the exact network segments involved in data transfer, it is suggested to use a simplified approach based on average values. An average value often used as standard (Aslan et al, 2017) determined the energy intensity for fixed line data transmission, Te, of 0.06 kWh/GB in 2015. As discussed in the same document, efficiency gains would put the current value of Te as 0.0075 kWh/GB. Hence, the energy expenditure associated with an X-Road data transfer, q, of size Dq shall be calculated as:

$$Emissions_{transfer,\, i} = T_e D_q G \qquad (4)$$

Here G is the emissions factor for electricity generation for the relevant country (Estonia or Finland). In cases of data transfer, between Estonia and Finland, an average value shall be used.

This chapter incorporated, which aspects are crucial and what is not in the scope. A list of abbreviations has been included to provide background information about the analysis that is explained in the latter part of this chapter. After highlighting the subsystems that are not taken into account, the study proceeds on to explain the critical operations that are part of the calculations. A small explanation of the selected use-cases sets the expectations of how the environmental impact analysis will be drawn. Lastly, a standardized robust methodology is explained that consists of two models. These models will cover the main operations of an X-Road instance and help to conclude accurate environmental emissions.

Summary

Current report outlined the initial results of the study and built grounds for X-Road carbon footprint calculation that is expected to be carried out in February to March 2021. Please give us feedback, that help us improve the outcomes!

Appendix 1. Project timeline for information

Timeline		Week																				
Task	**Participants**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1. Mapping of X-Road instance and use-case selection	20.01.2021-22.02.2021																					
2. Environmental footprint evaluation of the use-cases	15.02.2021-31.03.2021																					
3. Embedding the environmental footprint data to working practices	17.03.2021-28.05.2021																					
4. Design and improvements to the report	20.05.2021-17.06.2021																					