Appendix D – Agriculture Sector Methodology

April 2024

EGDC ICT Methodology

EUROPEAN GREEN DIGITAL COALITION

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DIGITAL COALITION

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The European Green Digital Coalition (EGDC) is an initiative of companies, supported by the European Commission and the European Parliament, based on the request of the EU Council, which aims to harness the enabling emission-reducing potential of digital solutions to all other sectors.

The secretariat of the European Green Digital Coalition is managed by the consortium of the European Parliament Pilot Project for the EGDC, funded by the European Commission, namely the leading associations GeSI, the European DIGITAL SME Alliance, DIGITALEUROPE, ETNO and GSMA, working together with Carbon Trust, Deloitte, Sustainable ICT.

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Global Enabling Sustainability Initiative (Coordinator)

DIGITALEUROPE

European Telecommunications Network Operators' Association

European DIGITAL SME Alliance

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Sustainable ICT Consulting

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In addition, the case studies used in this methodology were received from the following organisations: Atea and Telia

Introduction

To ensure the digital transition reinforces the green transition, the European Green Digital Coalition (EGDC) was formed in March 2021 supported by the European Commission and the European Parliament, based on the request of the EU Council. The main aim of the EGDC is to maximise the sustainability benefits of digitalisation within the ICT sector, while supporting sustainability goals of other key sectors such as energy, transport, agriculture, and construction. EGDC members commit to contributing to the success of the green digital transformation of the EU and beyond by taking action in the following areas:

- To invest in the development and deployment of greener digital technologies & services that are more energy and material efficient,
- To develop methods and tools to measure the net carbon impact of green digital technologies on the environment and climate by joining forces with NGOs and relevant expert organisations,
- To co-create with representatives of other sectors recommendations and guidelines for green digital transformation of these sectors that benefits environment, society, and economy.

As a cross-cutting sector, the EGDC recognises that the ICT sector can deliver emissions reductions in other sectors through the development and deployment of new solutions that would otherwise not be possible and replace existing solutions with high associated emissions.

In order to affirm, communicate and maximise the intended impact of the solutions that are being enabled by digital technologies, it is crucial that their impact is being measured in a robust and consistent way. Responding to this need and following from the EGDC Declaration, the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" was developed to provide a methodology for the ICT sector to develop methods and tools to measure the net impact of ICT solutions on the environment and climate.

While this methodology is sector agnostic and aims to provide a set of requirements for assessing the net carbon impact of ICT solutions in any implementation context, there are many sector-specific challenges and specificities that need to be considered. This document aims to support users of the EGDC methodology with developing net carbon impact assessments for ICT solutions implemented across different sectors, by offering a demonstration of how the individual requirements from the EGDC methodology can be applied using practical examples from sector specific case studies.

The aim of this document is therefore to demonstrate the application of the EGDC methodology for ICT solutions implemented in the agriculture sector. To achieve this aim, the following ICT solutions that have been developed into case study calculators as part of the EGDC Pilot Project will be used:

- **Atea, GlobeTrack** – This ICT solution was submitted to be developed into a case study calculator by Atea as part of the EP Pilot project. GlobeTrack is a blockchain solution that tracks fish stock transport across cold-chain stages from Norway to a municipal district in Sweden. This tracking technology monitors food stock data metrics such as temperature and location during transport to reduce fish stock wastage, enable more efficient and sustainable value chains. and improve food quality and traceability for customers.
- **Telia, Ekobot** – This ICT solution was submitted to be developed into a case study calculator by Telia as part of the EP Pilot project. Ekobot is an autonomous, electric field robot for mechanical weed control. It allows for efficient and environmentally conscious farming. Ekobot identifies and mechanically removes weeds using advanced camera sensors and AI. It enables reductions in the use of chemicals on the field for healthier crops, soil, and produce.

While these case studies do not necessarily illustrate best practice applications of the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions", they provide a realistic application that aims to demonstrate how the methodology can be used under different circumstances. Furthermore, this document highlights where a case study has not fulfilled the criteria and details steps that would need to be taken in order for the criteria to be fulfilled.

How to use this document

This document mirrors for the most part the requirements laid out in sections 3, 4 and 6 of EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions". As such, it should be used in conjunction with the requirements and guidance laid out in the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" and used as a reference point to illustrate how each requirement can be applied in practice for solutions in the agriculture sector. Note that while the examples provided in these documents could be applied to other ICT solutions in this sector, they are not prescriptive and other approaches to meeting the requirements in the "Net Carbon Impact Assessment Methodology for ICT Solutions" can be applied if appropriate.

Methodology Application in the Agriculture Sector

This section outlines all requirements in the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" for ICT solutions that impact emissions in the agriculture sector. The application for each requirement is shown using two ICT solutions that impact the emissions in the agriculture sector. Certain requirements are combined if it made sense to illustrate the application of these requirements together. This may also affect the order of the requirements in some cases.

Defining the Assessment

Assessment Objective

The assessor shall define the following:

(A) Assessment aim: Describe the intended use of the output from the assessment

Atea, GlobeTrack

The assessment intent is to determine to what extent the Atea GlobeTrack solution can have a net positive impact on cold-chain transport of fish stocks based on a pilot group study. Furthermore, the aim of the assessment was also to test the EGDC "ICT Sector Guidance for Net Carbon Impact Assessments" and identify sector-specific methodological considerations.

Telia, Ekobot

The assessment intent is to understand the net carbon impact of the Ekobot solution implemented in a pilot group of crop fields. Furthermore, the aim of the assessment was also to test the EGDC "ICT Sector Guidance for Net Carbon Impact Assessments" and identify sector-specific methodological considerations.

(B) Assessment type: Define if the assessment will consider a single implementation context or if multiple contexts will be carried out.

Atea, GlobeTrack

The assessment considers one implementation context, namely Norwegian fish cold-chain supply for a single product.

Telia, Ekobot

The assessment only considers one implementation context, namely the deployment of Ekobot in Sweden operating on onion fields.

(C) Assessment perspective (actual / potential effect): Determine if an ex-post or ex-ante assessment is to be carried out.

Atea, GlobeTrack

The assessment is ex-ante, estimating the potential impact from future deployment opportunities in Norway using data from pilot study.

Telia, Ekobot

The assessment is ex-post, determining the actual effect of the ICT solution by analysing data from a 2-month trial in 2022 after the implementation of the solution.

Solution Description & Boundary

The ICT solution to be assessed shall be clearly defined including:

(A) A description of the ICT solution and its functionality.

Atea, GlobeTrack

GlobeTrack is a blockchain solution that tracks fish stock transport across cold-chain stages from Norway to a municipal district in Sweden. This tracking technology monitors food stock data metrics such as temperature and location during transport to reduce the instances of fish stock wastage due to temperature errors. This enables emissions avoidance through reduced fish stock wastage and avoided additional transport of stock across Norwegian supply chains.

Telia, Ekobot

Ekobot is an autonomous field robot that surveys crop fields to identify and mechanically remove weeds using advanced camera sensors and Artificial Intelligence. It enables emissions avoidance through three mechanisms: reduced tractor fuel usage, reduced use of chemicals on fields and increased yield/productivity per field.

(B) The key mechanism(s) by which the ICT solution is expected to result in changes to GHG emissions.

Atea, GlobeTrack

Reduced food waste: GlobeTrack integrated solution uses active sensors to monitor fish conditions such as temperature, pH etc. Data exported to GlobeTrack blockchain cannot be manipulated, altered or deleted. Thus, it serves as an incentive to maintain the correct temperature during transport. The technology enables documentation of cold-chain breaches and prevents thawing/ waste by setting temperature threshold alerts that warn both driver, operator and owner that a potential breach is in progress. Improved tracking of stock temperatures reduces the occurrence of food wastage due to temperature errors across cold-chain stages.

Avoided transport: Implementation of GlobeTrack reduces the likelihood of banned trucks per year. Trucks are normally stopped at random and checks of food stock performed. If a temperature error is spotted the truck journey is abandoned, returning to the origin to re-start journey with new produce. Improved tracking of food cargo along cold-chain decreases rate of truck re-calls/abandoned journeys due to temperature errors of frozen fish stock, therefore the solution enables fuel savings from the additional mileage that banned trucks must re-start after an error is detected.

Telia, Ekobot

Improved fuel efficiency: Ekobot manually removes weeds so reduces the need for conventional tractors to complete the same task, thus reducing fuel usage.

Reduction in chemical use: For conventional (non-organic) farms, Ekobot operations reduce the need for chemical treatments to remove weeds. This reduces the emissions associated with chemical use and their wider impacts on biodiversity and soil health.

Improved crop yield per field: For conventional (non-organic) farms, Ekobot operations increase the yield per field, which reduces the overall GHG emissions associated per unit of crop.

(C) The sector(s) in which the ICT solution is expected to be implemented.

Atea, GlobeTrack

The GlobeTrack solution is expected to have an impact in the agriculture sector, specifically food distribution.

Telia, Ekobot

The Ekobot solution is expected to have an impact in the agriculture sector.

(D) Any limitations to the use of the solution (e.g., geographical, technical, operational, etc.).

Atea, GlobeTrack

The assessment is limited by the geographical boundary of the pilot project. The solution was trialled in Sweden (Helsingborg). However, the solution calculation boundary covers Norwegian cold-chain transport so results may be limited by geographical representativeness. Access to network infrastructure is also an operational limitation of the solution. It requires a connection to a network therefore would be limited to locations where this infrastructure is available.

Telia, Ekobot

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The assessment of net carbon impact is limited to a specific crop type (onions) as testing was only performed on these fields.

(E) The ICT solution boundary as a description of all components comprising the solution.

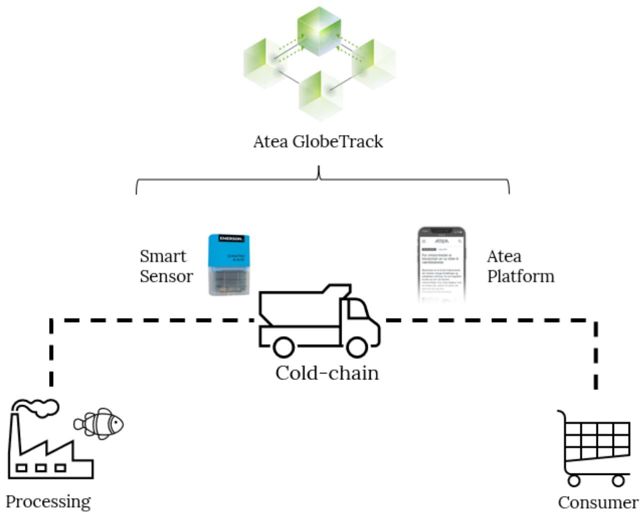
Atea, GlobeTrack

Digital components:

The solution's integrated operations are controlled by Atea's digital blockchain platform. The data transfer/storage is provided through blockchain distributed servers. Furthermore, the ICT solution receives in-field data from GO Real-time active sensors through 4G/5G network.

Non-digital components:

Every truck is equipped with a minimum of one GO Real-Time 4G/5G Tracker with a SIM-card to monitor food stock along cold-chain journey, sending data via 4G/5G network to the Atea platform.



Telia, Ekobot

Digital components:

The autonomous robot intermittently connects to a cloud-based server. Ekobot estimates this to have been 2 vCPU during the trial.

Non-digital components:

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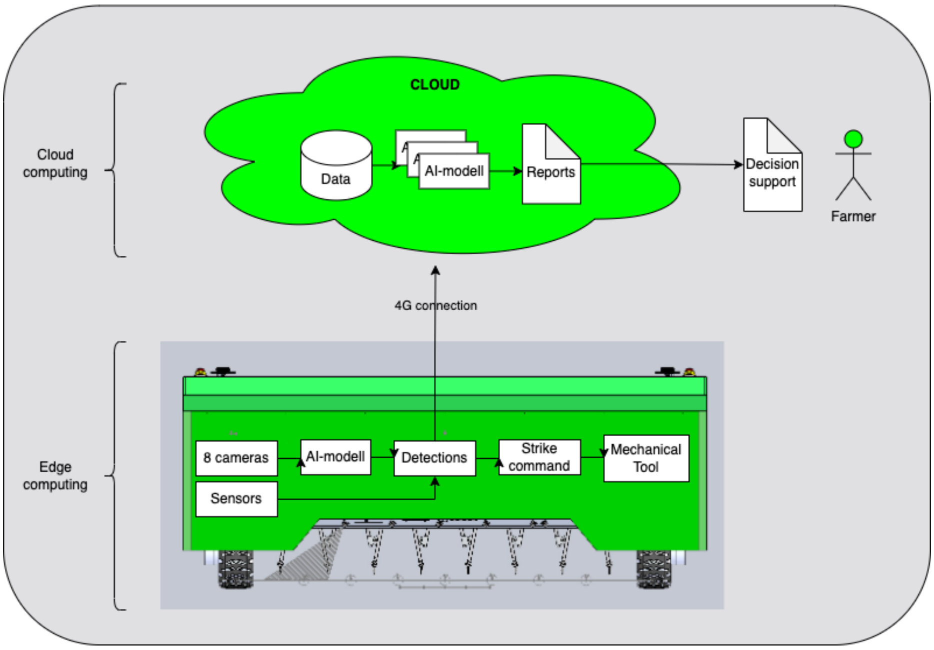
The manufacturing of the robot has associated embodied emissions. The following parts of the robot (464kg) have been noted and included within the assessment: robot's frame including electronics, roof, wheel system, gearboxes, tool carrier, tool engines and tool frames, Li-ion battery and battery case, electrical wiring/hardware, tool glider, wheels.



Functional Unit

(A) The functional unit for the assessment shall be defined including descriptions of its:

(i) Function relevant to both reference and enabled scenarios

(ii) Unit quantity

(iii) Performance

Atea, GlobeTrack

The functional unit for the solution is **kilogrammes of CO2 equivalent saved for a single truck journey within Norway.**

The function that the ICT solution is aiming to deliver is improved efficiency of food stock delivery across cold-chain distribution stages.

The unit quantity is the number of truckloads of food stock successfully delivered.

The performance is the monitored efficiency of successful truck deliveries within a year.

Telia, Ekobot

The functional unit for the solution is **kilogrammes of CO2 equivalent saved per tonne of yield per season.**

The function that the ICT solution is aiming to deliver is improved tonnes of crop yield and associated energy intensity.

The unit quantity is the improved tonnes of yield per season.

The performance is related to the improved efficiency of crop yield, in tonnes, within the crop growing season. Tonnes of yield was chosen to reflect a possible increase in yield after the introduction of the solution.

Assessment Boundary

The assessment boundary determines which activities should be included in the net carbon impact assessment and therefore which emissions are included in the calculation.

(A) All GHGs covered by the Kyoto Protocol shall be included in the assessment and reported in a single CO2e value in alignment with common greenhouse gas reporting standards.

(B) The assessor shall define the time boundary for the assessment.

Atea, GlobeTrack

The time boundary for the assessment is a single year, 2022.

Telia, Ekobot

The time boundary for the assessment is a single year. The trial period in Sweden lasted two months.

(C) The assessor shall define the geographical boundary for the assessment.

Atea, GlobeTrack

The geographical boundary for the assessment is cold-chain distribution within Norway and Sweden.

Telia, Ekobot

The geographical boundary for the assessment is 2 hectares of crop fields in Sweden.

(D) The assessor shall define the implementation context for the assessment.

Atea, GlobeTrack

The implementation context is based on a pilot study of 12 cargo trucks distributing fish to Helsingborg district, Sweden.

Telia, Ekobot

The solution has been implemented across onion crop fields in both Sweden and Netherlands. The trial period in Sweden was for 2 months. The farm in the Netherlands did not qualify for the trial since the measurements were not deemed reliable enough.

Reference Scenario Definition

(A) The reference scenario shall be determined as what the most likely alternative scenario in the event the solution is not/was not implemented, and it shall:

(i) Have equivalent or less functionality than the ICT solution.

(ii) Be relevant to the given implementation context.

(iii) Be relevant to the time in which the ICT solution is being assessed.

(B) The most likely scenario is determined as either:

(i) Continued use of the known system that was previously in place.

(ii) Use of the average alternative solution/method that solution users would select to achieve the same service.

Atea, GlobeTrack

The reference scenario considered is no active tracking of food stocks using distributed blockchain technology across cold-chain stages. This is supported by Norwegian freight distribution statistics, related to food wastage and haulage.

Telia, Ekobot

The reference scenario considered is a conventional farm in Sweden, where two hectares of an onion field were tracked in a block trial; one block weeded by the robot and one block treated by chemicals. The trial lasted 2 months and there were several reference blocks.

(C) The reference scenario shall include multiple scenarios if necessary to accurately represent the most likely alternative scenario.

Atea, GlobeTrack

The assessment has potential to include multiple reference scenarios i.e., comparing GlobeTrack against other market-average tracking technologies. However, from secondary sources used it was not possible to split out the activity data to this level of granularity (non-tracked vs tracked freight along cold-chain). If data became available, testing multiple reference scenarios could help to improve the accuracy of the assessment.

Telia, Ekobot

For the assessment it was deemed not relevant to include multiple scenarios as the measured reference scenario was specific to a single crop type. There is potential to include multiple reference scenarios for different crops and geographies, which was explored. For example, a parallel trial was done in the Netherlands but did not qualify as measured data was deemed not reliable enough.

(D) The assessor shall describe how the function is fulfilled in the reference scenario.

Atea, GlobeTrack

In the reference scenario it is assumed that the tracking of food stock along cold-chain is done manually at cold-chain checkpoints.

Telia, Ekobot

In the reference scenario, weeding of crop fields is done through combination of manual labour and chemical treatment.

Identifying Effects

Identifying Reference and ICT Solution Scenario Activities and Emission Sources

(A) Identify the activities under the reference and ICT solution scenarios.

Atea, GlobeTrack

The following activities were identified as activities under both the reference and ICT enabled scenarios.

Reference scenario	ICT enabled scenario
Fish stock tonnage per cargo	Fish stock tonnage per cargo
Truck mileage	Truck mileage
Truck journeys per year	Truck journeys per year
Proportion of truck recalls	Proportion of truck recalls

Telia, Ekobot

The following activities were identified under the reference and ICT enabled scenarios:

Reference scenario	ICT enabled scenario
Type of crop field	Type of crop field
Field size (hectares)	Field size (hectares)
Crop yield (tonnes/hectare)	Crop yield (tonnes/hectare)
Tractor operations (hours/hectare)	Tractor operations (hours/hectare)
Tractor fuel use (litres/hectare)	Tractor fuel use (litres/hectare)
Pesticide use (kg/hectare)	Pesticide use (kg/hectare)

(B) Identify potential GHG emission sources related to the activities.

Atea, GlobeTrack

Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources
Fish stock tonnage per cargo	Food waste emissions	Fish stock tonnage per cargo	Food waste emissions
Truck mileage	Transport emissions	Truck mileage	Transport emissions
Truck journeys per year	Transport emissions	Truck journeys per year	Transport emissions
N/A	N/A	Solution embodied and use-phase emissions	Hardware embodied emissions (truck sensor, SIM Card) Solution in-use emissions (truck sensor energy use) Network emissions (4G/5G) Data centre processing and storage emissions

Telia, Ekobot

Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources
Type of crop field	Agriculture emissions	Type of crop field	Agriculture emissions
Field size (hectares)	Agriculture emissions	Field size (hectares)	Agriculture emissions

Crop yield (tonnes/hectare)	Agriculture emissions	Crop yield (tonnes/hectare)	Agriculture emissions
Tractor operations (hours/hectare)	Transport emissions	Tractor operations (hours/hectare)	Transport emissions
Tractor fuel use (litres/hectare)	Transport emissions	Tractor fuel use (litres/hectare)	Transport emissions
Pesticide use (kg/hectare)	Agriculture emissions	Pesticide use (kg/hectare)	Agriculture emissions
N/A	N/A	Solution embodied and use-phase emissions	Hardware embodied emissions (Ekobot component parts, SIM Card) Solution in-use emissions (Ekobot energy use) Network emissions (3G/4G) Data centre processing and storage emissions

Identifying Potential Effects of Solution Implementation

(A) Identify the potential effects generated by the implementation of the ICT solution.

Atea, GlobeTrack

Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources	GHG emission impacts
Fish stock tonnage per cargo	Food waste emissions	Fish stock tonnage per cargo	Food waste emissions	Reduction in Food waste emissions
Truck mileage	Transport emissions	Truck mileage	Transport emissions	Reduction in Transport emissions
Truck journeys per year	Transport emissions	Truck journeys per year	Transport emissions	Reduction in Transport emissions
N/A	N/A	Solution embodied and use-phase emissions	Hardware embodied emissions (truck sensor, SIM Card) Solution in-use emissions (truck sensor energy use) Network emissions (4G/5G) Data centre processing and storage emissions	Increase in emissions from hardware, solution electricity consumption, network emissions and data centre storage.

Telia, Ekobot

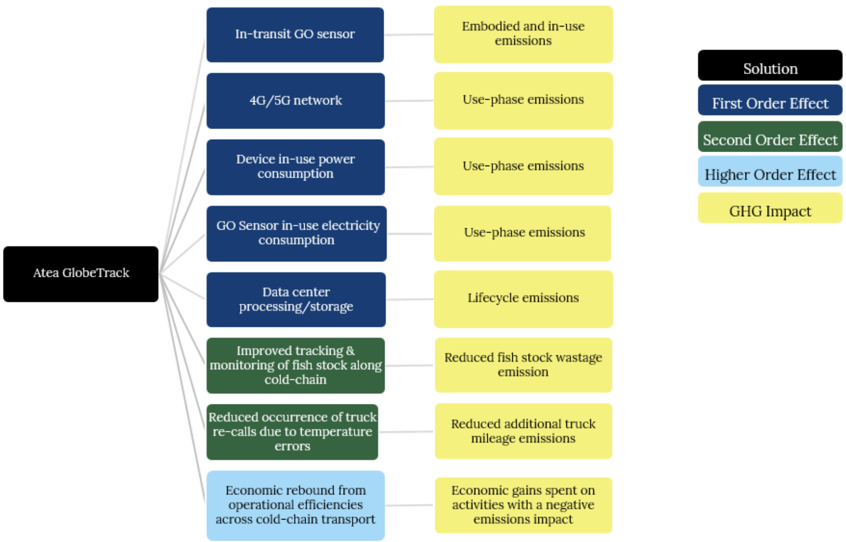
Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources	GHG emission impacts
Type of crop field	Agriculture emissions	Type of crop field	Agriculture emissions	Reduction in agriculture emissions
Field size (hectares)	Agriculture emissions	Field size (hectares)	Agriculture emissions	Reduction in agriculture emissions
Crop yield (tonnes/hectare)	Agriculture emissions	Crop yield (tonnes/hectare)	Agriculture emissions	Reduction in agriculture emissions
Tractor operations (hours/hectare)	Transport emissions	Tractor operations (hours/hectare)	Transport emissions	Reduction in transport emissions
Tractor fuel use (litres/hectare)	Transport emissions	Tractor fuel use (litres/hectare)	Transport emissions	Reduction in transport emissions
Pesticide use (kg/hectare)	Agriculture emissions	Pesticide use (kg/hectare)	Agriculture emissions	Reduction in agriculture emissions
N/A	N/A	Solution embodied and use-phase emissions	Hardware embodied emissions (robot component parts) Solution in-use emissions (robot energy use)	Increase in emissions from robot hardware, solution electricity consumption network and

			Network emissions (3G/4G) Data centre processing and storage emissions	data centre storage.

Mapping Effects in a Consequence Tree

(A) Map out all first, second, and higher order effects and GHG impacts in a consequence tree.

Atea, GlobeTrack



Telia, Ekobot

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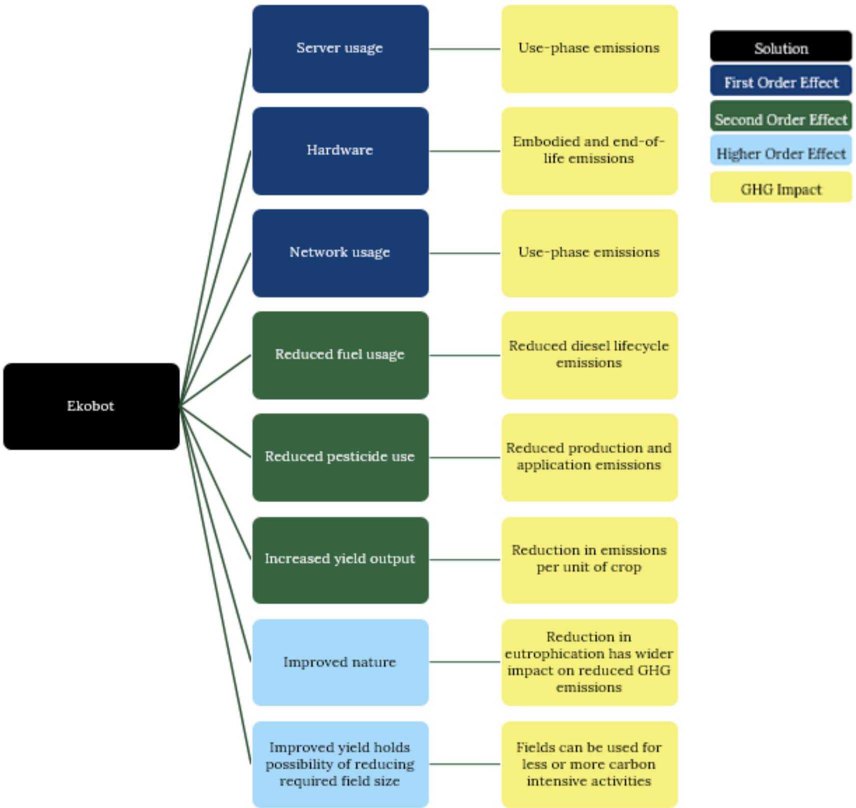

Identify First Order Effects

(A) All first order effects shall be identified that occur within the boundary of the ICT solution as defined in section 3.2.2 of the “Net Carbon Impact Assessment Methodology for ICT Solutions”.

(B) The GHG impact of first order effects shall consider the full life cycle emissions of the ICT solution, that are not excluded by (C). This includes upstream emissions relating to solution’s manufacture and transportation (embodied emissions), life cycle emissions from use and maintenance, and end of life treatment.

(C) Embodied and end-of-life emissions from ICT equipment or hardware that can be justified as already in existence without the solution implementation can be excluded from the calculation of first order effects with justification.

Atea, GlobeTrack

The following emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Embodied (incl. transport), end-of-life and in-use emissions of hardware** (cargo sensors) – as this hardware was not required before the implementation of the solution and is not part of the reference scenario, both the embodied and in-use emissions and should be considered for the calculation of first order effects.
- **In-use emissions from laptop/mobile devices using GlobeTrack platform**
    - The marginal increase in **in-use power consumption from devices using GlobeTrack platform** are not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of devices using GlobeTrack platform** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Network emissions (4G/5G)**
    - The marginal increase in **in-use network emissions** is not part of the reference scenario and therefore should be considered for the calculation of first order effects.
    - The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data centre processing and storage emissions**
    - The marginal increase in **in-use emissions from data centre processing and storage** are not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely

for this solution. These emissions are therefore excluded from the calculation of first order effects.

Telia, Ekobot

The following emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Embodied (incl. transport), end-of-life and in-use emissions of hardware** (robot component parts) – as this hardware was not required before the implementation of the solution and is not part of the reference scenario, the embodied, in-use, and end-of-life emissions and should be considered for the calculation of first order effects.
- **Network emissions (3G/4G mobile and fixed)**
  - The marginal increase in **in-use network emissions** is not part of the reference scenario and therefore should be considered for the calculation of first order effects.
  - The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data centre processing and storage emissions**
  - The marginal increase in **in-use emissions from data centre processing and storage** is not part of the reference scenario and therefore should be considered as first order effects.
  - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

Identify Second & Higher Order Effects

(A) All second order effects shall be identified.

(B) All higher order effects shall be identified.

Atea, GlobeTrack

The following second and higher order effects were identified:

Second order effects:

- A reduction in fish stock wastage from pre-mature thawing along cold-chain stages. This is a result of improved monitoring and tracking through GlobeTrack platform.
- A reduction in truck transport resulting from reduced occurrence of journey re-calls. Due to improved monitoring and tracking of fish products along cold-chain stages there is a reduced rate of temperature error detections and truck re-calls.

Higher order effects:

- Economic rebound - Optimisation of fish stock tracking could result in a scenario where a cost saving is realised by the supplier due to more efficient cold-chain logistics. This may inadvertently drive-up demand for fish stocks due to a reduction in transport costs overheads. This scenario was identified however not quantified due to lack of available data.

Given the potential system-wide scope of higher order effects, it should be acknowledged that this is not necessarily an exhaustive list and other higher order effects may be identified.

Telia, Ekobot

The following second and higher order effects were identified:

Second order effects:

- Reduction in tractor fuel consumption to manually weed crop fields.
- Reduction in use of chemical pesticides to treat weeds in fields.
- In conventional farms, Ekobot operations enable increased yield per field, which reduces the overall GHG emissions associated per unit of crop.

Higher order effects:

- Ekobot operations reduce chemical use in conventional farms which contributes to wider environmental benefits in crop fields i.e. protecting biodiversity, reducing soil and water pollution. In long-term this would indirectly drive down associated emissions in the surrounding environment.
- As crop yield per field increases as result of optimised farming practices, in long-term this would reduce land requirements, at scale, to produce same quantity of produce. Hence drive emissions reductions across farm operations.

Given the potential system-wide scope of higher order effects, it should be acknowledged that this is not necessarily an exhaustive list and other higher order effects may be identified.

Calculating Effects

Estimating the Relative Magnitude of Effects

(A) An estimation of the magnitude of effects included in the assessment should be carried out for all identified GHG impacts resulting from first, second, and higher order effects.

Atea, GlobeTrack

First order effects:

The hardware of the solution (cargo sensors) is unlikely to have a large embodied and in-use GHG emissions footprint relative to other effects, considering the weight of sensor equipment and the relatively small power drawn during lifetime use. The calculations still aim to include this effect but may rely on secondary or proxy data if necessary. The energy consumption related to administering the solution via solution software, data transmission across the network, and data centre processing and storage is likely to account for most of the first order effects. Therefore, these should be the focus areas for obtaining high quality data within the first order effects, data centre processing metrics from solution users.

Second order effects:

Initial results show that savings in food stock tonnage make up vast majority of material impact (>94%) for the assessment boundary. Given the high carbon intensity associated with food waste, the reduction in waste emissions from improved tracking accounts for majority GHG savings from second order effects, and high data quality should therefore be a priority for this effect. Reduced transport emissions have a much smaller impact (<5%) however should be a focus area for obtaining higher data quality.

Higher order effects:

It is extremely difficult to assess the magnitude of higher order effects as their impact is highly uncertain. The identified potential higher order effect (economic rebound resulting from optimised cargo transport & distribution) is generally speculative, and evidence of its existence would take longer time periods to materialise than the first and second order effects. The potential economic rebounds from optimised T&D are limited by the cost savings achieved but may be material if these savings are large enough to encourage additional supply of cold-chain products to be distributed. Therefore, effort should be made to track these impacts and their drivers to understand if any rebound is experienced.

Telia, Ekobot

First order effects:

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The hardware components of the Ekobot solution have a large embodied and in-use GHG emissions footprint relative to other effects (>50%). This is considering the large number of material components (aluminium, steel, Li-ion battery) and combined weight of the Ekobot solution. The lifecycle emissions of these components are included in calculation, using material-specific emission factors. The robot also uses significant energy consumption to power the robot over growing season. These inputs were taken from primary trial data so considered high quality and should be focus areas for obtaining high quality data within the first order effects. Emissions associated with administering the solution via software transmission, network usage and data centre processing and storage are likely to have negligible impact on the first order effects. The calculations still aim to include this effect but may rely on secondary or proxy data if necessary.

Second order effects:

Ekobot's trial study indicates a tractor time saving and pesticide reduction of 18% and ~25% (respectively). Therefore, the expected reduction in both fuel use and reduced pesticide use are likely to account for a large part of the GHG savings from second order effects, and high data quality should be a priority for this effect.

Higher order effects:

The identified potential higher order effects (wider environmental benefits of reduced pesticide use; reduced land use) could contribute significant impact to emissions reduction however would take longer time periods to materialise than the first and second order effects. Additionally, to understand the magnitude of pesticide use on wider environment would require significant monitoring of nature-based markers/metrics that was outside of scope of assessment boundary. Therefore, effort should be made to track land use, biodiversity, pollution impacts and their drivers to understand if any rebound is experienced.

Data Collection

Identifying Key Activities for each Effect

(A) For all effects identified under section 3.3 of the "Net Carbon Impact Assessment Methodology for ICT Solutions", suitable activities and activity emission intensities should be identified that can be used to estimate the GHG impact of each effect.

Atea, GlobeTrack

Effect	Description	Activities

First Order	Embodied (incl. transport), end-of-life and in-use emissions of hardware: - cargo sensors	• Number of sensors per functional unit • Cradle to grave footprint of hardware components (sensors) • Material breakdown of sensor (type and weight of material) • Material embodied and end-of-life emission factors • Energy usage per sensor per journey • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use network emissions	• Marginal energy consumption of network due to GlobeTrack blockchain platform • Network energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to GlobeTrack blockchain platform. • Data transmission energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from laptop/mobile devices using GlobeTrack platform	• Marginal energy consumption of devices using GlobeTrack blockchain platform.

		• Data transmission energy intensity (kWh energy use per GB data transfer per device) • Electricity grid emission factor (GHG emissions per kWh)
Second order	A reduction in fish stock wastage due to improved tracking and monitoring of cargo along cold-chain stages.	• Tonnage of fish stock delivered before and after the implementation of GlobeTrack solution. • Food waste emission factor (kgCO2e/kg)
Second order	A reduction in the occurrence of truck journey re-calls. This results from improved monitoring and tracking of fish products along cold-chain stages.	• Additional distance travelled by re-called trucks, by freight class, before and after implementation of GlobeTrack solution. • Transport emissions intensity by vehicle type (kgCO2e/km)
Higher order	Economic rebound - Optimisation of fish stock tracking resulting in a scenario where a cost saving is realised by the supplier due to more efficient cold-chain logistics.	• Tonnage of fish stock delivered before and after the implementation of GlobeTrack solution, several years after implementation. • Additional distance travelled by re-called trucks, by freight class, before and after implementation of GlobeTrack solution, several years after implementation. • Additional truck journeys completed before and after implementation of GlobeTrack solution, several years after implementation.

Telia, Ekobot

Effect	Description	Activities
First Order	Embodied (incl. transport), end-of-life and in-use emissions of hardware: – robot component parts	• Number of robots per functional units • Cradle to grave GHG emissions footprint of robot material components • Material breakdown of hardware (type and weight of material) • Material embodied and end-of-life emission factors • Annual energy usage per robot • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use network emissions	• Marginal energy consumption of network due to solution • Amount of data transfer over the network • Network energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from Ekobot software data centre processing and storage	• Marginal energy consumption of Ekobot software use and data processing in data centres (vCPU-hours) • CPU carbon intensity (GHG emissions per CPU) • Electricity grid emission factor (GHG emissions per kWh)

Second order	A reduction in tractor fuel consumption	• Tractor utilisation time (hours) • Tractor fuel consumption within utilisation time (litres/hour) before and after the implementation of the solution • Diesel fuel emission factor (kgCO2e/litre)
Second order	A reduction in pesticide use	• Quantity (kg) of pesticides used by type (6 variants) before and after the implementation of the solution • Pesticide emission factor, by chemical type (kgCO2e/kg)
Second order	Ekobot operations enable increased yield per field, which reduces the overall GHG emissions associated per unit of crop	• Increase in yield (tonnes) per hectare across different field types (conventional, organic)
Higher order	Reduction in chemical use in conventional farms which contributes to long-term environmental benefits in crop fields i.e. protecting biodiversity, reducing soil and water pollution.	• Assessment of nature-based indicators (biodiversity, soil health, pollution in conventional fields before and after the implementation of solution, several years after implementation.
Higher order	Increased crop yield per field in long-term leads to reduced land requirements, at scale, to produce same quantity of produce.	• Crop yield per field before and after the implementation of solution, several years after implementation. • Crop field utilisation before and after the implementation of solution, several years after implementation.

Data Quality and Availability Assessment

(A) A data availability and quality assessment should be carried out for all activities and activity emission intensities identified for each effect included in the assessment. The assessment shall be used to select the most appropriate data sources for the assessment.

(B) The data availability and quality assessment can then be used to select relevant data sources for the net carbon impact assessment by considering the following:

(i) The data quality and availability for each activity under both the reference and ICT solution scenario.

(ii) The ITU L1410 guidance for data quality and data quality review guidance.

(iii) The relative magnitude of the effect.

(C) All data sources and assumptions used when selecting applicable data should be documented and reported.

Atea, GlobeTrack

Effect	Activities	Data for activity available?	Data Quality
Embodied (incl. transport), end-of-life and in-use emissions of hardware: - cargo sensors	• Number of sensors per functional unit • Cradle to grave footprint of hardware components (sensors) • Material breakdown of sensor (type and weight of material) • Material embodied and	• Yes – assumed 1 per vehicle • No • Some - Weight data available, No data for material breakdown • Yes • No • Yes	• Good • N/A • Poor – proxy material data • Good – BEIS material factors • Proxy data for IoT device power rating • Good - Publicly available electricity grid emission factors

	end-of-life emission factors • Energy usage per sensor per journey • Electricity grid emission factor (GHG emissions per kWh)		
In-use network emissions	• Marginal energy consumption of network due to GlobeTrack blockchain platform • Network energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)	• No • No • Yes	• Poor – proxy data and assumptions of network carbon intensity • Same as above • Good - publicly available electricity grid emission factors
In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to GlobeTrack blockchain platform. • Data transmission energy intensity (kWh energy use per GB data transfer)	• No • No • Yes	• Poor for all – Proxy data for data transfer/storage emissions • Same as above • Good - publicly available electricity grid emission factors

	• Electricity grid emission factor (GHG emissions per kWh)		
A reduction in fish stock wastage due to improved tracking and monitoring of cargo along cold-chain stages.	• Tonnage of fish stock delivered before and after the implementation of GlobeTrack solution. • Food waste emission factor (kgCO2e/kg)	• Yes – primary data for implementation scenario. Secondary data for reference scenario. • Yes	• Fair – accounting for mix of quality data • Good – BEIS factors
A reduction in the occurrence of truck journey re-calls. This results from improved monitoring and tracking of fish products along cold-chain stages.	• Additional distance travelled by re-called trucks, by freight class, before and after implementation of GlobeTrack solution. • Transport emissions intensity by vehicle type (kgCO2e/km)	• Yes – primary data for implementation scenario. Secondary data for reference scenario. • Yes	• Fair – accounting for mix of quality data • Good – BEIS factors
Economic rebound - Optimisation of fish stock tracking resulting in a scenario where a cost	• Tonnage of fish stock delivered before and after the implementation of GlobeTrack solution, several	No data available	• N/A

saving is realised by the supplier due to more efficient cold-chain logistics.	years after implementation. • Additional distance travelled by re-called trucks, by freight class, before and after implementation of GlobeTrack solution, several years after implementation. • Additional truck journeys completed before and after implementation of GlobeTrack solution, several years after implementation.		

Telia, Ekobot

Effect	Activities	Data for activity available?	Data Quality
First Order	• Number of robots per functional units • Cradle to grave GHG emissions footprint of robot material components	• Yes – assumed 1 per crop field • No • Some - Weight data available, No data for	• Good • N/A • Poor – proxy material data • Good – Publicly available material

	• Material breakdown of hardware (type and weight of material) • Material embodied and end-of-life emission factors • Annual energy usage per robot Electricity grid emission factor (GHG emissions per kWh)	material breakdown • Yes • Yes • Yes	factors (incl. BEIS) • Very Good – primary data • Good - Publicly available electricity grid emission factors
First Order	• Marginal energy consumption of network due to solution • Network energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)	• Not quantified	• N/A
First Order	• Marginal energy consumption of Ekobot software use and data processing in data centres (vCPU-hours)	• No • No • Yes	• Poor – Proxy data for data CPU data transfer/storage emissions • Same as above

	• CPU carbon intensity (GHG emissions per CPU) • Electricity grid emission factor (GHG emissions per kWh)		• Good - publicly available electricity grid emission factors
Second order	• Tractor utilisation time (hours) • Tractor fuel consumption within utilisation time (litres/hour) before and after the implementation of the solution • Diesel fuel emission factor (kgCO2e/litre)	• Yes – primary data for both implementation reference scenario. • Yes • Yes	• Very Good – from Ekobot pilot study • Same as above • Good – BEIS factors
Second order	• Quantity (kg) of pesticides used by type (6 variants) before and after the implementation of the solution • Pesticide emission factor, by chemical type (kgCO2e/kg)	• Yes – primary data for both implementation reference scenario. • Yes	• Very Good – from Ekobot pilot study • Fair – publicly available conversion factors from secondary source (academic paper)

Second order	• Increase in yield (tonnes) across different field types (conventional, organic)	• Yes	• Fair – data from Ekobot pilot study of conventional vs organic fields, however completeness and reliability score low.
Higher order	• Assessment of nature-based indicators (biodiversity, soil health, pollution in conventional fields before and after the implementation of solution, several years after implementation.	• No data available	• N/A
Higher order	• Crop yield per field before and after the implementation of solution, several years after implementation. • Crop field utilisation before and after the implementation of solution, several years	• No data available	• N/A

	after implementation.		

First Order Effects

(A) The GHG impact of all first order effects shall be calculated for each implementation context within the boundary conditions except for those excluded by the cut-off criteria.

(D) First order effects shall be calculated for all life cycle phases of the solution.

(i) Embodied and end-of-life emissions shall be allocated equally across the lifetime of the solution and included according to the time period of the assessment

(ii) Use-phase emissions shall be calculated for the time period of the assessment.

(E) First order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance. If the functional unit requires multiple units of the solution or its components for the level of activity, as many units as required will be calculated.

(F) A conservative approach should be applied for all calculations of first order effects, i.e. emissions should rather be overstated than understated.

Atea, GlobeTrack

The embodied emissions of in-vehicle sensor hardware are calculated by allocating the weight of sensor by different material components and multiplying these by corresponding emission factors for each material type.

The marginal in-use emissions of in-vehicle sensors are calculated using power rating data for a typical mobile device, powered by a lithium-ion battery (conservative proxy data). The electricity consumption required to charge each sensor for a single journey was estimated. This consumption was multiplied by relevant electricity emission factor.

No direct data could be provided on network data usage for Atea solution. Emissions related to data transfer over 4G/5G network are estimated by multiplying assumed number of accesses to operate solution by proxy network energy intensity factor to obtain GHG emissions.

For in-use emissions from data centre processing and storage, no direct data from the server host could be obtained. This was estimated based on top-down calculation of blockchain energy intensity data. This was multiplied by the relevant country electricity emission factor.

For all data sources and calculation methodology refer to GlobeTrack case study methodology and calculator.

Telia, Ekobot

The embodied emissions of robot hardware components are calculated by allocating the weight of each material component and multiplying these by corresponding emission factors for each material type.

The in-use phase electricity consumption of Ekobot is calculated by multiplying the annual energy consumption requirements over its activity hours (provided by Ekobot) with an electricity grid carbon conversion factor to obtain GHG emissions.

Emissions related to network energy consumption were not quantified during assessment.

Emissions related to software use and data processing/storage were estimated by multiplying the estimated software utilisation rate (CPU-hour) by relevant carbon conversion factor to obtain GHG emissions.

(B) Cut-off criteria for first order effects:

(i) Solution components common between the reference and solution scenarios where the GHG impact has not been modified.

(ii) Where data availability prevents calculation of the GHG impact, first order effects may be excluded from the net carbon impact assessment if they can be demonstrated to be less than 5% of the total net carbon impact or net carbon impact per functional unit.

(iii) If multiple first order effects are considered for cut-off, the total effect must remain less than the 5% threshold.

(C) Exclusions of any first order effects from net carbon impact assessments shall be supported by clear justification and supporting calculation.

Atea, GlobeTrack

The impacts for the following first order effects were estimated to justify their exclusion from the calculations:

- In-use emissions from laptop/mobile devices using GlobeTrack platform – the marginal increase in device emissions were estimated through a materiality assessment, performed in absence of available data. The emissions are excluded from the calculation as not expected to meet the 5% materiality threshold in terms of carbon savings (742 kgCO2e).

None of the excluded first order effects are estimated to be greater than 5% of the total net carbon impact of Atea GlobeTrack.

Telia, Ekobot

The impacts for the following first order effects were estimated to justify their exclusion from the calculations:

- Network emissions - The marginal increase in in-use network emissions have been excluded from the calculation on the principle that they are not expected to meet the 5% materiality threshold in terms of carbon savings (32 kgCO2e) when compared against proxy network carbon intensity metrics (kgCO2e/access)[1]. A live calculation is performed in the case study calculator.

None of the excluded first order effects are estimated to be greater than 5% of the total net carbon impact of Ekobot.

Second Order Effects

(A) The GHG impact of all identified second order effects (positive and negative changes to the reference scenario) shall be calculated for the same implementation context except for those excluded by the cut-off criteria.

(C) The GHG impact of second order effects shall be calculated with a life cycle perspective.

(D) The second order effect calculation shall exclude additional rebound usages in the quantification of the GHG impact.

(E) The second order effect calculation shall exclude existing occurrence of the second order effect from other similar ICT solutions.

(F) Second order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance.

(G) If a net carbon impact assessment is to be used for public claims of a solutions' impact (including annual reporting) primary data should be used for either the reference or ICT solution scenario, or both.

(H) A conservative approach should be applied for all calculations of second order effects i.e. net positive emissions should rather be understated than overstated.

Atea, GlobeTrack

[1] https://www.telefonica.com/en/communication-room/reports/life-cycle-assessment/

The 2nd order effects are calculated for two mechanisms of avoided emissions from the implementation of the solution:

(1) Reduction in fish stock wastage (tCO2e/truck/year)

To calculate GHG savings, for both the reference and implementation scenario, the tonnage of fish transported per year was calculated by multiplying the average tonnage of fish transported per truck by the total number of truck journeys each year. The calculator includes override options for both tonnage of fish stock per truck and number of truck journeys as this input greatly impacts the likely emissions saving from food wastage.

The reference scenario assumes that each year, cold-chain logistics trucks follow routine transit checkpoints along their journey for quality control produce. If after these routine checks the fish stock has thawed due a temperature error, the cargo contents will be discarded as waste and the journey abandoned. The frequency/occurrence rate of banned/recalled cold-chain trucks was estimated based on the analysis of Norwegian transport statistics.

The same calculation approach is followed for the implementation scenario, using the occurrence rate (%) of expected truck recalls when Globe Track solution is in operation (blockchain data management platform supported by in-transit active sensors in trucks). This rate was sourced from Atea's five-month trial of the solution in the Swedish district of Helsingborg.

The difference between the reference scenario total tonnage of fish stock wasted (tonnes/year) and that of the implementation phase indicates the net avoided fish tonnage. The 2nd order emissions are then calculated using the emissions factor for food waste decomposition (kgCO2e/tonne).

(2) Reduction in truck transport resulting from reduced occurrence of journey re-calls (tCO2e/truck/year)

To calculate these GHG savings, for both the reference and implementation scenario, the number of trucks that are banned/recalled per year (due to cold-chain temperature errors) are multiplied by the average distance travelled per truck journey. Then, this is multiplied by the proportion (%) of journey trucks complete before being recalled and then doubled to account for the return journey distance trucks must travel to restart the cold-chain delivery from the original depo.

In the implementation scenario, the occurrence rate (%) of expected truck recalls/bans is reduced when deploying GlobeTrack solution in trucks. The same calculation approach is followed using Atea trial data.

The differential distance travelled by trucks (kilometres/year) between the reference scenario and the implementation scenario deduces the net avoided distance travelled by trucks. The 2nd order emissions are calculated using a distance-based emission factor for avoided truck distance travelled (kgCO2e/kilometre).

Telia, Ekobot

The second order effects calculation captures GHG savings achieved through the solution, by reducing tractor hours, herbicide use, and increasing yield per field. For each of these, measurements before and after the reference scenario are made with different numbers for conventional and organic farms.

The reduction in tractor use is measured in hours, with the assumption that on average a tractor uses 25L of diesel per hour whilst on the field (Grisso et al., 2010). The saved fuel is converted to saved CO2e.

The reduction in various types of chemical use is measured and their active ingredients are matched to the chemical type through the Swedish Chemical Inspection website, as suggested by Ekobot. Their associated CO2e conversion factors are used in the calculation (Cech, Leisch & Zaller, 2022)

The increased yield per hectare is used in the final savings per functional unit.

(B) Cut-off criteria for second order effects:

(i) GHG impacts from identified second order effects may be excluded from the net carbon impact assessment if they can be demonstrated to be less than 5% of the total net carbon impact or net carbon impact per functional unit. Positive second order effects of any magnitude may also be excluded (typically due to data availability).

(ii) If multiple second order effects are considered for cut-off, the total effect must remain less than the 5% threshold.

(iii) Cut-offs of any second order effects from net carbon impact assessments shall be supported by clear justification and supporting calculation.

Atea, GlobeTrack

No second order effects that were identified were excluded from the calculation.

Telia, Ekobot

No second order effects that were identified were excluded from the calculation.

Higher Order Effects

(A) A qualitative assessment shall be undertaken for all identified higher order effects, including how and where they would occur, within what timeframe, the expected magnitude, and the likelihood of the effect occurring. The strength of the relationship between the solution and the higher order effect should be considered and ideally be demonstrated by academic research.

Atea, GlobeTrack

Qualitative assessment of identified higher order effects:

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Economic rebound - Optimisation of fish stock tracking could result in a scenario where a cost saving is realised by the supplier due to more efficient cold-chain logistics. This could inadvertently drive-up demand for fish stocks due to a reduction in transport costs overheads. This scenario was identified however not quantified due to lack of available data.	Economic rebound could occur within the solution's system boundary, increasing supply of fish stocks across cold chain, resulting in increased emissions from truck freight movement and food waste.	Medium to Long term	Not quantified – unclear what likely cost savings from optimised tracking could be and limited data available to support this.	Occurrence is likely low – however limited data available to support this.	Yes – solution's optimisation of cold-chain operations would lead to direct economic rebound.

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Qualitative assessment of identified higher order effects:

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Ekobot operations reduce chemical use in conventional farms which contributes to wider environmental benefits in crop fields i.e. protecting biodiversity, reducing soil and water pollution. In long-term this would indirectly drive down associated emissions in the surrounding environment.	A reduction in pesticides has positive effects on surrounding nature through avoidance of eutrophication.	Medium term	Low	Medium	Difficult to ascertain but likely. There are many interlinked processes which may affect the chemical processes.
As crop yield per field increases as result of optimised farming practices, in long-term this would reduce land requirements, at scale, to produce same quantity of produce. Hence drive emissions reductions across farm operations.	An increase in yield may reduce the number of fields required, reducing ghg emissions	Medium term	Low	Low	Difficult to ascertain, e.g. may be reversed if better business performance allows a company to switch over to Ekobot.

(B) Where a quantitative assessment is possible, the GHG impact of all identified higher order effects (positive and negative) should be calculated for each implementation context within the boundary conditions.

(i) Significant effects shall not be excluded from quantitative assessment if robust data and knowledge of the effect exist.

(ii) Effects deemed significant but not quantifiable shall be supported by clear justification and reported alongside the net carbon impact quantitative results.

(iii) Effort should be made to collect necessary data or carry out necessary studies with the intention of quantitatively assessing the effect in the future and the exclusion shall be re-evaluated during the recalculation assessment**Error! Reference source not found.**.

(C) The GHG impact of higher order effects shall be calculated with a life cycle perspective, where it is feasible.

(D) Higher order effects shall be calculated in relation to the functional unit and for the level of activity defined by the functional unit performance.

(E) A conservative approach should be applied for all calculations of higher order effects, i.e. net positive emissions should rather be understated than overstated.

Atea, GlobeTrack

Higher order effect excluded due to lack of available data. This would require monitoring of effect over medium to long-term to realise whether effect is material, it is therefore not included within assessment boundary.

Telia, Ekobot

Higher order effects are excluded due to lack of available data. Their inclusion would require monitoring the effects over the medium to long-term to realise whether they are material, therefore they are not included within assessment boundary.

Net Carbon Impact Calculation

(A) The total net carbon impact of the solution shall be calculated including all quantified first, second, and higher order effects included in the assessment, for the time boundary of the assessment.

Atea, GlobeTrack

Net carbon impact: 14.84 tCO2e / year

1st order effects: 0.37 tCO2e / year

2nd order effects: 15.21 tCO2e / year

Net carbon impact per functional unit: 0.51 tCO2e / truck / year

Telia, Ekobot

Total carbon saved: 0.7 tCO2e / season

1st Order effects: 0.02 tCO2e

2nd Order effects: 0.62 tCO2e

Savings per functional unit: 5.1 kg CO2e / tonnes yield / season

(B) Significant changes to the calculated GHG impacts of first, second, or higher order effects during the time period of the assessment shall be included in the assessment.

Atea, GlobeTrack

Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

Telia, Ekobot

Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

Uncertainty and sensitivity analysis

(A) A sensitivity analysis should be carried out for all key parameters as part of the net carbon impact assessment.

Atea, GlobeTrack

The sensitivity analysis shows the impact of varying the inputs to the net impact calculation in different implementation contexts.

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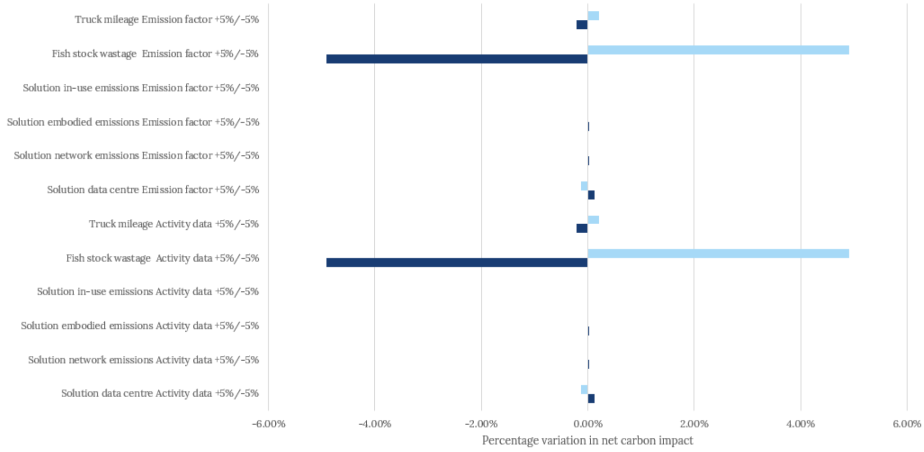
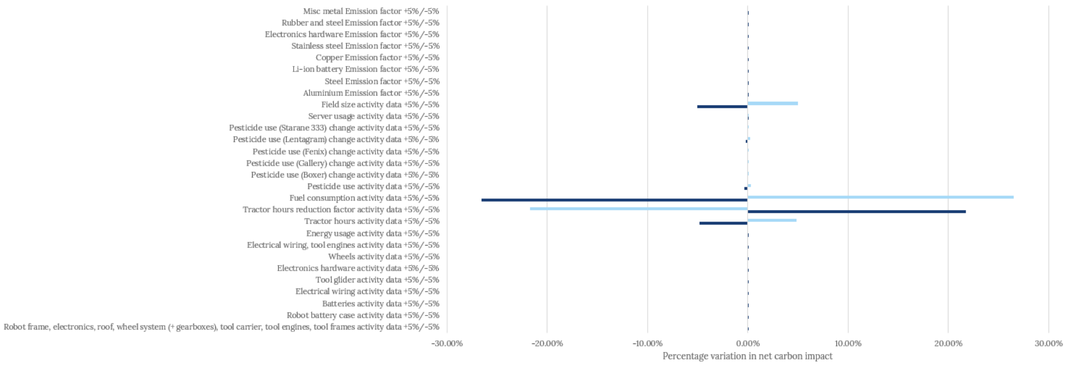
the European Union

The activity data of fish stock (weight) and its associated waste emission factor are the most sensitive inputs. When the activity data for fish stock is varied by -5%, the net carbon impact decreases to 14.1 tCO2e. Alternatively when the activity data is varied by +5%, the net carbon impact increases to 15.6 tCO2e.



Telia, Ekobot

Almost all variables score very low in the sensitivity analysis. However, variables related to fuel consumption score very high, indicating that the electrification of conventional tractors has a high carbon impact. For example, when activity data for fuel consumption varied by -5%, the net carbon impact decreases by 26.5%. Conversely, when the activity data is varied by +5%, the net carbon impact increases by 26.5%.



(B) A net carbon impact assessment should include an uncertainty analysis of the results.

Atea, GlobeTrack

The qualitative uncertainty analysis assesses the quality of the data inputs. It demonstrated that the assessment's uncertainty has a significant impact on the solution's net carbon impact, given the scale of the savings. Efforts should be made to improve the activity mileage and fish stock data particularly for the reference scenario, striving to collect primary data.

			Qualitative Assessment of Data Quality				
Data type	**Impact effect**	**Description of effect**	**Activity**	**Time**	**Geography**	**Reliability**	**Completeness**
Activity Data	1st order	Solution data centre	Poor	Fair	Poor	Fair	Poor
	1st order	Solution network emissions	Poor	Good	Fair	Fair	Fair
	1st order	Solution embodied emissions	Fair	Very Good	Very Good	Fair	Very Good
	1st order	Solution in-use emissions	Poor	Poor	Very Good	Fair	Fair
	2nd order - ICT enabled scenario	Fish stock wastage	Very Good	Fair	Poor	Fair	Fair
	2nd order - ICT enabled scenario	Truck mileage	Very Good	Fair	Poor	Fair	Good
	Reference scenario	Fish stock wastage	Good	Poor	Very Good	Fair	Fair
	Reference scenario	Truck mileage	Good	Poor	Very Good	Fair	Fair
Emission factors	1st order	Solution data centre	Very Good	Very Good	Very Good	Good	Good
	1st order	Solution network emissions	Very Good	Very Good	Very Good	Good	Good
	1st order	Solution embodied emissions	Good	Very Good	Good	Very Good	Good
	1st order	Solution in-use emissions	Very Good	Very Good	Very Good	Good	Good
	2nd order	Fish stock wastage	Good	Very Good	Good	Very Good	Good
	2nd order	Truck mileage	Good	Very Good	Good	Very Good	Good
	Reference scenario	Fish stock wastage	Good	Very Good	Good	Very Good	Good
	Reference scenario	Truck mileage	Good	Very Good	Good	Very Good	Good

It should be noted that the analysis performed is not a quantitative uncertainty analysis. By providing a more granular view of data quality, which builds on the data quality assessment, this analysis highlights areas of uncertainty within the calculation using a qualitative assessment framework. It can however be used to feed into a quantitative uncertainty analysis using guidance from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty: https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

Telia, Ekobot

The uncertainty analysis assesses the quality of the data inputs. It demonstrated that the assessment's uncertainty has a significant impact on the solution's net carbon impact, given the scale of the savings. Data quality is relatively good for first order emissions due to precise measurements to the robots' material components. The conversion factor used for server emissions is of bad quality but is immaterial in terms of carbon impact. Second order emissions are also relatively good except for organic farms, where limited measurements were taken.

It should be noted that the analysis performed is not a quantitative uncertainty analysis. By providing a more granular view of data quality, which builds on the data quality assessment, this analysis highlights areas of uncertainty within the calculation using a qualitative assessment framework. It can however be used to feed into a quantitative uncertainty analysis using guidance from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty: https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

Recalculation

(A) It may be suitable that an assessment calculated for one year can be repeated in following years without changes, however, the reference scenario, implementation context, assumptions, exclusions, methods, and data used shall be reviewed annually to be applicable before continuing to use the results of an assessment.

(B) If the review identifies necessary changes to the assessment that could change the results by more than 5%, recalculation in whole or part will be necessary.

(C) Recalculation of the assessment should take place at a maximum of three years after the original assessment to ensure its validity.

			Qualitative Assessment of Data Quality				
Data type		Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity Data	First order	Weight robot materials	Very good	Very good	Very good	Very good	Very good
		Energy usage robot	Good	Good	Good	Good	Good
		Server usage	Good	Good	Good	Fair	Fair
	Second order	Pesticide use	Very good	Very good	Good	Good	Fair
		Tractor use	Very good	Very good	Good	Good	Fair
		Yield outputs	Fair	Very good	Good	Fair	Poor
		Fuel efficiency	Good	Good	Good	Fair	Poor
Emission factors	First order	Conversion factors material production and end-of-life	Good	Very good	Very good	Good	Very good
		Conversion factors electricity grid	Good	Very good	Very good	Good	Very good
		Conversion factor server usage	Poor	Poor	Poor	Poor	Poor
	Second order	Conversion factors pesticides	Good	Very good	Very good	Good	Fair
		Conversion factors diesel	Good	Very good	Very good	Good	Very good

Atea, GlobeTrack

As the solution is nearly market average across Europe, the assessment will need to be reviewed annually to determine whether the reference scenario needs to be updated. This could cause results to change by more than 5%. Additionally, the reference scenario depends on fish cargo waste statistics and fleet mileage data that is likely to fluctuate year-to-year so would require recalculation of these effects.

Telia, Ekobot

Some first order effects were not included within this assessment, namely network emissions. Their inclusion has the potential to change results by 5%, although unlikely. To reduce this uncertainty, the assessment should be reviewed annually to determine the full contribution of first order effects to the solution's net carbon impact.

Other considerations for a net carbon impact assessment

Do No Significant Harm

Atea, GlobeTrack

The solution is not expected to cause significant harm in other ESG areas. Potential longer-term effects of the solution could be a reduction in the required number of vehicles/drivers, which could have an impact on employment.

Telia, Ekobot

The solution is not expected to cause significant harm in other ESG areas. Ekobot's focus on more efficient weed removal and agricultural processes, as well as its effect on non-GHG emissions (soil health and biodiversity) mean Ekobot may influence other ESG areas positively (e.g. biodiversity, human health).

Commented [OP1]: This is PREDRI not Ekobot

Using Results in Other Implementation Contexts

(A) The new implementation context shall have the same ICT solution scenario and reference scenario as the original net carbon impact assessment.

(B) The parameters of the original net carbon impact assessment should be adjusted to reflect the new implementation context.

(C) Where it is not possible to adjust the assessment parameters, the results should only be used in other implementation contexts if a review determines that the changes are not expected to significantly change the results or overestimate a positive impact.

Atea, GlobeTrack

The following includes a list of implementation parameters that may need to be adjusted in different implementation contexts:

- **Tonnage of fish cargo transported** – Cargo throughput of fish stocks expected to fluctuate year-to-year and differ across deployment countries. The weight of wasted cargo accounts for largest proportion of second order emissions so should always be monitored and strive for improvements to data quality for subsequent recalculations.
- **Average mileage travelled by trucks** – Mileage and routing of truck fleets would be expected to fluctuate year-on-year and between different deployment countries. Avoided mileage by trucks accounts for ~3% net impact so would need to be monitored and strive for improvements to data quality for subsequent recalculations.
- **Fuel efficiencies of trucks** – if the fuel efficiencies of trucks differ considerably to the fuel efficiency of the fleets in the assessment, this could impact the second order effects. Adjustments would be needed and could be addressed by using the differences in fuel used per km to adjust fuel usage data before and after the implementation of the solution.
- **Fuel type of trucks** – if the solution was applied in a different fleet, it is also likely that the fleet consists of vehicles with different fuel types. To take this into account, the emission factor would need to be adjusted and for EVs fuel usage may need to be converted into kWh used.
- **Types of vehicles** – in addition to using different fuels, a key parameter that could change across fleets is the classification of trucks that a fleet consists of. The current assessment is for a fleet of HGV trucks. A new assessment would need to be carried out to assess the impact of the solution if different truck fleets were deployed.
- **Different sensor suppliers** - If the suppliers of the hardware differ in the new implementation context, this could be updated and adjusted in the assessment. However, given the immateriality of these emissions to the overall net carbon impact, if data is not available or the new suppliers are unknown, the assessment could be used within this context without the need for adjustments.

Telia, Ekobot

The following includes a list of implementation parameters that may need to be adjusted in different implementation contexts:

- **Type of farm (organic vs conventional)** – The assessment of Ekobot net carbon impact on organic farms was based on limited measurement data. As organic farms are expected to have a higher yield per crop and use less pesticides than conventional fields, the carbon savings associated with Ekobot deployment on these fields is expected to be less. Future calculations should strive for improvements to data quality for organic fields.
- **Carbon intensity of fuel used by tractor** – this will change as the biomass content of diesel changes, as well as the well-to-tank emissions associated with the fuel (i.e., emissions from extracting, transporting and distributing fuel), as processes become more or less efficient. While the carbon intensity of transporting fuels has been decreasing, it is uncertain whether and how this will continue in the future, as demand for biofuel in other areas increases and the demand for fossil-based transport fuels decreases with a growing number of zero emission vehicles.
- **Fuel efficiencies of tractor** – if the fuel efficiencies of tractors differ considerably to the fuel efficiency of those in the assessment, this could impact the second order effects. Adjustments would therefore be needed and could be addressed by using the differences in fuel used to adjust fuel usage data before and after the implementation of the solution.

Communicating and Documenting Outcomes of a Net Carbon Impact Assessment

Communicating and documenting outcomes of a single ICT solution

Organisations communicating results from a net carbon impact assessment of a single ICT solution should disclose:

(A) The total net carbon impact, as well as a breakdown by first order, second order, and higher order effects included in the quantitative assessment.

(B) The qualitative assessment of all higher order effects deemed to be likely and/or of significant magnitude and any actions undertaken to mitigate the effect.

(C) Any other environmental impacts identified from the do no significant harm assessment and any actions undertaken to mitigate their effect.

(D) A description of the ICT solution and assessment including the reference scenario, assessment perspective (actual/potential), implementation context(s), and time period.

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(E) The organisation's contribution to the ICT solution and limitations to the calculation.

Organisations communicating results from a net carbon impact assessment of a single ICT solution are encouraged to disclose or provide on request:

(F) Documentation for the assessment including the boundary, calculation methodology, rationales (e.g. justification of reference scenario), assumptions, data sources and uncertainty of the results.

(G) A relative metric for the net carbon impact in relation to the business operations, e.g. percentage of total revenue associated with the solution.

Atea, GlobeTrack

The results of the assessment have been documented in a combined methodology document, which can be found here.

Telia, Ekobot

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