Appendix F – Smart Cities Sector Methodology

April 2024

EGDC ICT Methodology

EUROPEAN GREEN 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.

This deliverable has been produced by the consortium of the European Parliament Pilot project for the EGDC.

Global Enabling Sustainability Initiative (Coordinator)	DIGITALEUROPE	European Telecommunications Network Operators' Association	European DIGITAL SME Alliance

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EUROPEAN GREEN DIGITAL COALITION

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

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 smart cities sector. To achieve this aim, the following ICT solution that has been developed into a case study calculator as part of the EGDC Pilot Project will be used:

- **Nokia, Smart waste management** – The Integrated Operations Center (IOC) platform is a digital enablement platform that increases productivity, efficiency and growth through the agile introduction and largely automated utilization of digital operational technology assets and capabilities. It is part of the Smart City project of the Nicosia municipality in Cyprus, where it is used to provide information on waste bin fillings for bin collection route optimisation and traffic information using video analytics to reduce overall transport emissions and pollution levels. Currently, the calculator only assesses the impact from the waste bin management application.

While this case study does not necessarily illustrate best practice applications of the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions", it provides 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 the 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 smart cities 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 Smart Cities 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 smart cities sector. The application for each requirement is shown using an ICT solution that impacts the emissions in the smart cities 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.

Nokia, Smart waste management

The assessment intent is to determine to what extent the Nokia smart waste management solution can have a net positive impact on the smart cities sector when implemented in a specific context. 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.

The outputs from the assessment of Nokia's Integrated Operations Center (IOC) platform as a smart waste management solution are intended for educational and informational purposes. The assessment exemplifies the practical application of the EGDC methodology to a real-life use case and identifies areas of improvements within its calculations.

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

Nokia, Smart waste management

The assessment considers the implementation of the Nokia's IOC platform smart waste management solution in two contexts, the collection of underground bins and glass recycling bins in the Municipality of Nicosia in Cyprus. Therefore, the results may not be representative for other implementation contexts.

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

Nokia, Smart waste management

The assessment is ex-post, determining the actual effect of the ICT solution by analysing two months of data after the implementation of the solution in 25 underground bins and 17 glass recycling bins.

Solution Description & Boundary

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

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

Nokia, Smart waste management

The Integrated Operations Center (IOC) platform is a digital enablement platform that increases productivity, efficiency and growth through the agile introduction and largely automated utilization of digital operational technology assets and capabilities. It is part of the Smart City project of the Nicosia municipality in Cyprus, where it is used to provide information on waste bin fillings for bin collection route optimisation and traffic information using video analytics to reduce overall transport emissions and pollution levels. Currently, the assessment only considers the impact from the waste bin management application.

The waste management solution entails the placement of Sensoneo Quatro sensors in bins. These sensors measure the fill-level in bins through ultrasonic technology. These then connect to existing IOT networks or GPRS to transfer data in real time to the IOC platform where it is analysed and communicated to its users via a website dashboard or smartphone app. Based on the data, bin collection routes are re-arranged so that only bins that exceed 50% fill capacity are emptied. The implementation context consists of trucks completing the same bin collection route, but only stopping at the bins whose fill capacity exceed the 50% threshold. This results in a reduction in bin collection stops, over the same route distance, which reduces the garbage trucks' idle fuel consumption when completing the collection routes as fewer stops are effectuated.

Future iterations of the solution look to apply further developed route optimization capabilities which aim to decrease truck fuel consumption due to decreased collection route lengths. However, for this assessment this implementation context is out of scope.

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

Nokia, Smart waste management

Optimising bin collection routes: Nokia's IOC platform analyses and identifies which bins exceed 50% of their fill capacity, and then communicates an optimised bin collection route. This results in a reduction in bin collection stops as trucks complete the same bin collection route, but only stopping at the bins whose fill capacity exceed the 50% threshold. Consequently, garbage trucks' idling fuel consumption when completing the collection routes is reduced as fewer stops are effectuated, which cuts GHG emissions.

Additional impacts:

A more efficient and shorter average bin collection route results in fuel savings. If less fuel is purchased, the organisation deploying the solution can experience economic savings from the reduced fuel costs. However, the spending of these cost savings may result in positive or negative GHG impacts depending on what type of activities they are spent on.

The smart wase management solution could also lead to GHG savings if the drivers acquire knowledge on fuel efficiencies and use it to improve their driving behaviour. In the long term this could lead to vehicles and/or vehicle parts being replaced less frequently. On a system-level this could reduce the demand to produce new vehicles, saving GHG emissions during the manufacturing process.

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

Nokia, Smart waste management

The Nokia's smart waste management solution is expected to have an impact in the smart cities sector, specifically around waste management.

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

Nokia, Smart waste management

A limitation is the types of bins being collected, as the collection time is dependent on the type of bin being collected and may require different processes. Additionally, some bin collections entail the use of water to wash the bins. The water consumption is out of scope for this assessment due to lack of data and the potential variability between the types of bins in the implementation context.

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

Nokia, Smart waste management

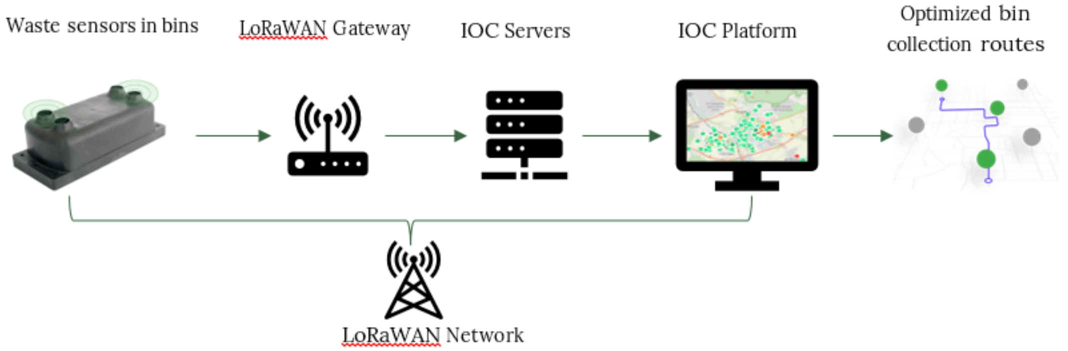
Digital components:

Sensoneo Quatro sensors are placed in bins to detect waste fill levels. The sensors transfer this data to the IOC platform and based on the analysis of bin fill levels, collection routes are modified accordingly.

The data transfer required for the solution between the sensors and the IOC servers and IOC platform is provided by a LoRaWAN network via a LoRaWAN gateway and antenna. Furthermore, the ICT solution requires laptops or mobiles to inform the operators of the solution and drivers of the vehicles.

Non-digital components:

Underground bins, glass recycling bins, and garbage trucks (HGVs 7.5-15 tonnes).



Images from: https://sensoneo.com/product/ultrasonic-bin-sensors/

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

Nokia, Smart waste management

The functional unit for the solution is **tonnes of CO2 equivalent saved per bin per year.**

The unit per bin was chosen to allow for the comparison between different bin quantities and varying collection route lengths.

The function that the ICT solution is aiming to efficiently collect waste bins along bin collection routes.

The unit quantity is the number of bins collected.

The performance is the speed and efficiency with which the waste bin collections occur within a year.

The quantity of bins directly impacts the duration of a bin collection route as a garbage truck stops at each bin to collect the waste. Therefore, the quantity of bins captures the number of stops in a collection route and has a direct impact on the fuel consumed by the garbage trucks in each stop.

The tons of CO2 equivalent per bin is considered an adequate functional unit as the number of bins remains the same across the reference scenario and ICT enabled scenario and because as the number of bins changes, the savings also change proportionally.

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.

Nokia, Smart waste management

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO2e. Furthermore, the well-to-tank emissions are also included in the emission factor.

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

Nokia, Smart waste management

The time boundary for the assessment is a year (2022), for which data of a trial period of 2 months has been extrapolated based on 10-months of garbage weight data for 2022.

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

Nokia, Smart waste management

The geographical boundary for this assessment is the municipality of Nicosia in Cyprus.

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

Nokia, Smart waste management

The solution has been implemented across 17 glass recycling bins and 25 underground bins in the municipality of Nicosia's waste management system. The implementation context consists of the trucks completing bin collection routes in the Municipality of Nicosia for these glass and underground bins, but only stopping at the bins whose fill capacity exceed the 50% threshold.

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.

Nokia, Smart waste management

The reference scenario is no active management or optimisation of the bin collection routes through technology and no real-time data is available to support decision making. The reference scenario measures the known number of bins collected in 2022, which equates to the number of bin collection stops per collection trip, and the collection trip duration prior to the smart waste solution implementation. The baseline is based on data for the full year. The market average scenario was not researched in this assessment because the specific reference scenario was known.

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

Nokia, Smart waste management

The reference scenario for the specific implementation contexts of glass recycling and underground bins in the Municipality of Nicosia in 2022 is known.

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

Nokia, Smart waste management

In the reference scenario, garbage truck drivers complete a bin collection route by stopping at each bin in the route to collect the waste no matter the fill level. Therefore, the number of bins is equivalent to the number of stops along the route, during which garbage trucks consume fuel when idling at each stop. This baseline was chosen in accordance with the provided data on the collection routes and bins that would be affected by the implementation of the solution to capture a reasonable 'before' scenario.

In the reference scenario, there is no technology-enabled route optimisation and there is no detailed, real-time data to support decision making.

Identifying Effects

Identifying Reference and ICT Solution Scenario Activities and Emission Sources

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

Nokia, Smart waste management

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

Reference scenario	ICT enabled scenario
Bin collection route	Bin collection route
Bin collections stops	Bin collections stops
Truck fleet maintenance	Truck fleet maintenance
Bin collection route management	Optimised bin collection route management

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

Nokia, Smart waste management

Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources
Bin collection route	Truck fuel consumption emissions	Bin collection route	Truck fuel consumption emissions

Bin collections stops	Truck idling fuel emissions	Bin collections stops	Truck idling fuel emissions
Truck fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	Truck fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities
Bin collection route management	Office emissions Hardware embodied and in-use emissions (LoRaWAN Gateway) Personal computers (PCs) emissions	Optimised bin collection route management	Office emissions Hardware embodied and in-use emissions (Waste sensors, LoRaWan Antenna, LoRaWAN Gateway) Network emissions (LoRaWan) Personal computers (PCs) emissions (access IOT platform software) Data centre processing and storage emissions (Waste and IOC server)

Identifying Potential Effects of Solution Implementation

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

Nokia, Smart waste management

Reference scenario	Potential emission sources	ICT enabled scenario	Potential emission sources	GHG emission impacts
Bin collection route	Truck fuel consumption emissions	Bin collection route	Truck fuel consumption emissions	No change in truck fuel consumption for driving portion of the bin collection route
Bin collections stops	Truck idling fuel emissions Bins embodied emissions	Bin collections	Truck idling fuel emissions Bins embodied emissions	Reduction in the truck idling fuel consumption and emissions due to reduced collection stops No change to bin embodied emissions.
Truck fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	Truck fleet maintenance	Site emissions from workshop Electricity and process emissions from maintenance activities	No change to emissions

Bin collection route management	Office emissions Hardware embodied and in-use emissions (LoRaWAN gateway). Personal computers (PCs) embodied emissions	Optimised bin collection route management	**Software only:** Office emissions Network emissions (LoRaWan) Personal computers (PCs) embodied and in-use emissions (access IOT platform software) Data centre processing and storage emissions (Waste and IOC server) **Including hardware:** Hardware embodied and in-use emissions (Waste sensors, LoRaWan Antenna, LoRaWan Gateway)	No change to office emissions. No change to LoRaWAN Gateway embodied and in-use emissions. Increase in emissions from hardware (sensors, antenna), network, PCs (IOC platform use) and data centre servers.

Mapping Effects in a Consequence Tree

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

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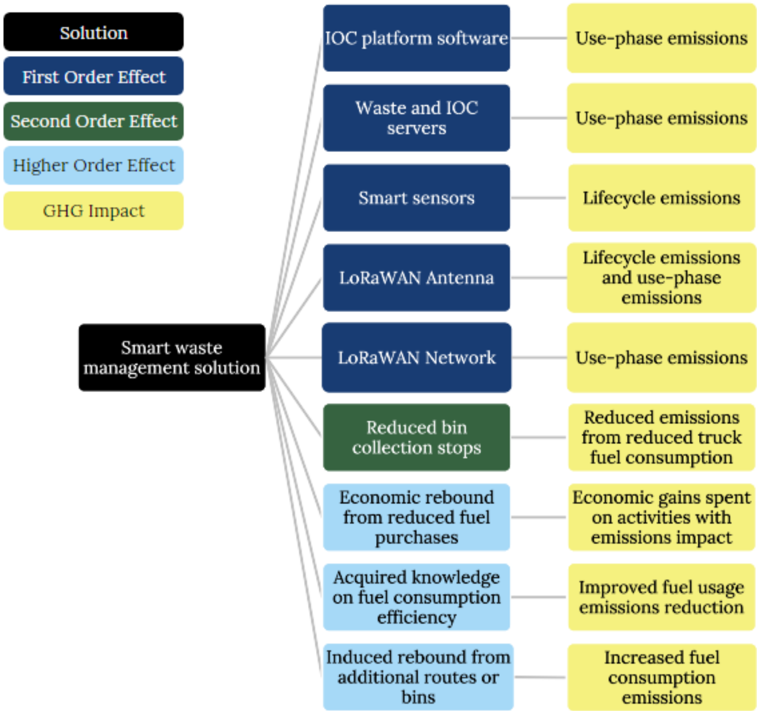

Identify First Order Effects

(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.

Nokia, Smart waste management

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 (Waste sensors, LoRaWan Antenna)**

  - 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.

- **Network emissions (LoRaWAN)**
  - The marginal increase in **in-use network emissions** are 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.

- **Personal computer emissions**
  - The marginal increase in **in-use emissions from PCs used to access and run the IOC 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 the PCs** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

- **Data centre processing and storage emissions (Waste and IOC servers)**
  - The marginal increase in **in-use emissions from data centre processing and storage (Waste and IOC servers)** 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.

Identify Second & Higher Order Effects

(A) All second order effects shall be identified.

(B) All higher order effects shall be identified.

Nokia, Smart waste management

The following second and higher order effects were identified:

Second order effects:

A reduction in fuel consumption from truck idling due to optimised routing which decreases the number of bin collection stops. Reduced stops lead to reduced truck fuel consumption when idling during bin collection stops, which translates to decreased GHG emissions.

Higher order effects:

- Reduction in fuel costs and associated economic impacts from the spending of these cost savings, which could lead to an increase/decrease in GHG emissions.
- Acquired knowledge of fuel efficiency can improve fuel usage in other areas, reducing emissions. Additionally, it can improve driver behaviour and in the long-term result in vehicles and/or vehicle parts being replaced less frequently, saving GHG emissions from the manufacturing process.
- A rebound from the addition of bins to the bin collection route based on the solution's use, could lead to increased fuel consumption and GHG emissions.

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.

Nokia, Smart waste management

First order effects:

Embodied (incl. transport), end-of-life and in-use emissions of hardware (waste sensors, LoRaWAN antenna) – Relative to the magnitude of potential carbon savings, these emissions were estimated to be material based on the weight of the devices, their material composition and the relatively small power consumption of the antenna (~10W based on similar devices[1]). The calculations should include this effect but may rely on secondary or proxy data if necessary.

Server processing and storage emissions, network emissions (LoRaWAN) and PCs to access the IOC platform emissions marginal increase in **in-use emissions –** the in-use emissions from PCs are assumed to be relatively small given that the calculations only account for the marginal increase in emissions caused by the use of the software needed to operate the solution. Given the lack of primary data available and low materiality, these emissions are likely to be excluded. The Waste and IOC server, as well as the network emissions, on the other hand, while also assumed to be relatively small, are considered to be more significant, given the amount of data being transferred.

Second order effects:

Initial results show a fuel saving of around 54% for the underground bins and 38% for the glass recycling bins, which amount to around 655 and 13 litres of fuel respectively for the assessment boundary. Given the high carbon intensity of diesel, it is assumed that the reduction in transport emissions from the reduction in truck stopping time, reduced idling fuel consumption is likely to account for a large part of the GHG savings from second order effects, and high data quality should therefore be a priority for this effect.

Higher order effects:

It is extremely difficult to assess the magnitude of the higher order effects as evidence of their existence would take longer time periods to materialise than the first and second order effects. The impact for the economic rebound could be positive, if the reduction in costs change expenditure to lower carbon activities or it could increase emissions if the reverse was the case. As the higher order effects identified are generally speculative, effort should be made to track these impacts in order 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.

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[1] https://www.cisco.com/c/en/us/td/docs/routers/connectedgrid/antennas/installing-combined/b-cisco-industrial-routers-and-industrial-wireless-access-points-antenna-guide/m-ant-lpwa-db-o-n-5.html [Accessed: 26/11/2023]

Nokia, Smart waste management

Effect	Description	Activities
First Order	Embodied (incl. transport), end-of-life and in-use emissions of hardware Sensoneo quatro sensors LoRaWAN antenna	• Number of devices per functional unit • Cradle to grave footprint of hardware devices • Material breakdown of hardware devices (type and weight of material) • Likely disposal method of devices • Energy usage per device over lifetime • Power consumption of device and usage profile • Material emissions factors incl. end-of-life (GHG emissions per unit)
First Order	In-use network emissions	• Marginal energy consumption of network due to the Nokia IOC. • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions of PCs to access IOC platform emissions used to operate the solution	• Marginal energy consumption of PCs due to operation of the IOC platform software. • Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from Waste and IOC servers for processing and storage	• Marginal energy consumption of data centres due to Nokia's IOC.

		• Electricity grid emission factor (GHG emissions per kWh)
Second order	A reduction in fuel consumption due to decreased collection route stops and reduced HGV idling time.	• Truck fuel consumption by fuel type when idling at bin collection stops for collection routes before and after the implementation of Nokia's IOC. • Fuel emission factor (GHG emissions per unit)
Higher order	An increase in fuel consumption and GHG emissions due to rebound from the addition of bins to collection route based on the solution's use.	• Fuel consumption before and several years after the implementation of the smart waste management solution. • Number of bins and bin collection stops before and several years after implementation of Nokia's IOC.
Higher order	Reduction in fuel costs and associated economic impacts from the spending of these cost savings, which could lead to an increase/decrease in GHG emissions.	• Products/services delivered before and several years after implementation of Logic TMS. • Cost of purchasing fuel before and several years after implementing Nokia's IOC. • Likely spending habits of customers before and several years after implementing Nokia's IOC.
Higher order	Acquired knowledge of fuel efficiency can improve fuel usage in other areas, reducing emissions.	• Total fuel consumption of garbage truck drivers before and several years after implementation of Nokia's IOC.

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.

Nokia, Smart waste management

Effect	Activities	Data for activity available?	Data Quality
Embodied (incl. transport), end-of-life and in-use emissions of hardware	• Number of devices per functional unit • Cradle to grave footprint of hardware devices • Material breakdown of hardware devices (type and weight of material) • Likely disposal method of devices	• Yes –1 per sensor per bin • No • Yes • No • Yes • N/A / No • Yes	• Good • Not available so calculated based on weight, materials and lifetime • Good – weight and main material used to estimate embodied emissions • Poor – assumed • Battery type and lifetime provided for sensor and proxy product used for antenna

	• Energy usage per device over lifetime • Power consumption of device and usage profile • Material emissions factors incl. end-of-life (GHG emissions per unit)		energy use and lifetime. • N/A as sensors are battery powered so not applicable, and Poor for antenna as no usage profile available • Good - publicly available and reliable sources for material emission factors
In-use network emissions	• Marginal energy consumption of network due to solution • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Good- Transmission data provided by Nokia • Good – publicly available and reliable source for electricity emission factor (AIB, 2022)
In-use emissions of PCs to access IOC platform emissions used to operate the solution	• Marginal energy consumption of PCs due to operation of the IOC platform software. • Electricity grid emission factor (GHG emissions per kWh)	• No • Yes	• Poor -Use of secondary data and proxies as primary data was not available • Good – publicly available and reliable source for electricity emission factor (AIB, 2022)

In-use emissions from Waste and IOC servers for processing and storage	• In-use emissions from Waste and IOC servers for processing and storage • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Good - Total Watts of electricity consumed by Waste and IOC servers per hour provide by Nokia. • Good – publicly available and reliable source for electricity emission factor (AIB, 2022)
A reduction in fuel consumption due to decreased collection route stops and reduced HGV idling time.	• Truck fuel consumption by fuel type when idling at bin collection stops for collection routes before and after the implementation of Nokia's IOC. • Fuel emission factor (GHG emissions per unit)	• Yes, fuel consumption for a year (measured data) before smart waste management solution implementation. • Yes, fuel consumption (measured data) from directly after smart waste management solution implementation • Yes	• Good • Fair – measured data 4 weeks to 2 months after implementation. • Good – publicly available and reliable source for electricity emission factor (BEIS, 2022)

Potential increase in fuel consumption and GHG emissions due to rebound from the addition of bins to collection route based on the solution's use.	• Fuel consumption before and several years after the implementation of the smart waste management solution. • Number of bins and bin collection stops before and several years after implementation of Nokia's IOC.	• No, data not available for several years after implementation of Nokia's IOC.	• Not applicable
Potential reduction in fuel costs and associated economic impacts from the spending of these cost savings, which could lead to an increase/decrease in GHG emissions.	• Products/services delivered before and several years after implementation of Logic TMS. • Cost of purchasing fuel before and several years after implementing Nokia's IOC. • Likely spending habits of customers before and several years	• No, data not available for several years after implementation of Nokia's IOC. • No data/information on spending habits available and information would be difficult to get.	• Not applicable

	after implementing Nokia's IOC.		
Acquired knowledge of fuel efficiency can improve fuel usage in other areas, reducing emissions.	• Total fuel consumption of garbage truck drivers before and several years after implementation of Nokia's IOC.	• No, data not available for several years after implementation of Nokia's IOC.	• Not applicable

Based on the data availability and quality assessment, the following higher order activities are excluded from the analysis:

- Reduction in fuel costs and associated economic impacts from the spending of these cost savings, which could lead to an increase/decrease in GHG emissions.
- Acquired knowledge of fuel efficiency can improve fuel usage in other areas, reducing emissions. Additionally, it can improve driver behaviour and in the long-term result in vehicles and/or vehicle parts being replaced less frequently, saving GHG emissions from the manufacturing process.
- A rebound from the addition of bins to the bin collection route based on the solution's use, could lead to increased fuel consumption and GHG emissions.

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.

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The first order effects calculation captures the lifecycle emissions of the battery-powered sensors and the LoRaWAN antenna that were installed for the use of the digital solution. The sensors' embodied and end-of-life emissions were calculated according to the weight and material composition of the sensors. The resulting emissions were divided by the sensor lifetime to obtain a "per year" impact. The battery's lifecycle emissions were calculated separately as an annual figure, as their lifetime differed from that of the sensor, and then were added to the sensor's annual impact. The embodied and end-of-life emissions of the LoRaWAN antenna were calculated similarly to those of the sensor.

The first order effects also include the emissions arising from the energy consumption of the waste and IOC servers, LoRaWAN antenna and network. The emissions of the servers and antenna were calculated by multiplying the yearly energy consumption, derived from power data provided (Watts), of the devices by the corresponding electricity emission factor. The annual data transmission over the network, which reflects the data transfer from the sensors to the antenna, was calculated based on the daily rate of transmissions and average packet size (GB). Then, the energy consumption per gigabyte transferred was multiplied by the annual data transmission figure to obtain the network's annual energy consumption. Applying the electricity lifecycle emission factor results in the yearly emissions from the network usage.

A materiality assessment was carried out for the IOC platform software energy consumption because of the lack of primary data for its calculation. The overall impact of the IOC platform emissions (from user access) was estimated to be immaterial, accounting for between 0.1% - 1.6% of the net GHG savings impact. Therefore, since it falls below the 5% inclusion threshold set out in the methodology, the emissions were not included in the solution's calculations.

(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.

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A materiality assessment was carried out for the IOC platform software energy consumption because of the lack of primary data for its calculation. The overall impact of the IOC platform emissions (from user access) was estimated to be immaterial, accounting for between 0.1% - 1.6% of the net GHG savings impact. Therefore, since it falls below the 5% inclusion threshold set out in the methodology, the emissions were not included in the solution's calculations.

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.

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The second order effects calculation captures CO_2 savings achieved through optimising bin collection, resulting in the reduction of collection stops for bins that were below 50% of fill capacity.

To calculate the carbon saving from the solution, the calculator measures the difference in bin collection stopping time in collection routes (in minutes) per year before and after the implementation of the sensors. To capture the reduced truck idling fuel consumption from avoided stops, the total time savings are multiplied by the hourly diesel consumption of idling HGVs (3.03 L/h).

Finally, an emissions factor for diesel (3.17 kgCO2e/litre) was applied to reach the final figure of 1.81 tCO_2e/year saved by the solution via its application to the existing 17 glass recycling bins and 25 underground bins that comprise the municipality of Nicosia's waste management system. It should be noted that the total net carbon savings for the glass recycling bins were negative because the first order effect outweighed the positive second order effect for this implementation of the solution. However, the net carbon savings from the underground bins were much larger in magnitude, causing the total savings for all bins to be positive.

(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.

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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.

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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?
Economic Rebound	A reduction in fuel consumption could lead to a reduction in fuel purchases, leading to cost savings. The spending of these cost savings could lead to an increase/decrease in GHG emissions depending on which activities they are spent on.	Medium	Low/Medium	Medium	Medium
Acquired knowledge of fuel efficiency	Acquired knowledge of fuel efficiency based on the solution implementation, for example around the waste fill levels of bins along a route and the frequency of their collection, can improve fuel usage in other areas, reducing emissions.	Medium/Long	Low	Low	Low

Rebound from the addition of bins	Rebound from the addition of bins to the bin collection route based on the solution's use, could lead to increased fuel consumption and GHG emissions.	Medium	Medium	Low	Medium

(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.

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Based on the data availability and quality assessment, the identified higher order effects do not have sufficient data to be quantitively assessed. The qualitative assessment of the higher order effects demonstrates the low likelihood of occurrence and lack of evidence of a causal relationship between the solution and the higher order effect. Therefore, they are excluded from the net carbon impact assessment.

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

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Total net carbon impact: 1.92 tCO_2e / year

Savings from reference scenario (underground bins): 54% truck idling fuel saved

Savings from reference scenario (glass recycling bins): 38% truck idling fuel saved

Saving per functional unit (underground bins): 0.078 tCO_2e / bin / year

Saving per functional unit (glass recycling bins): -0.002 tCO_2e / bin / year

(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.

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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.

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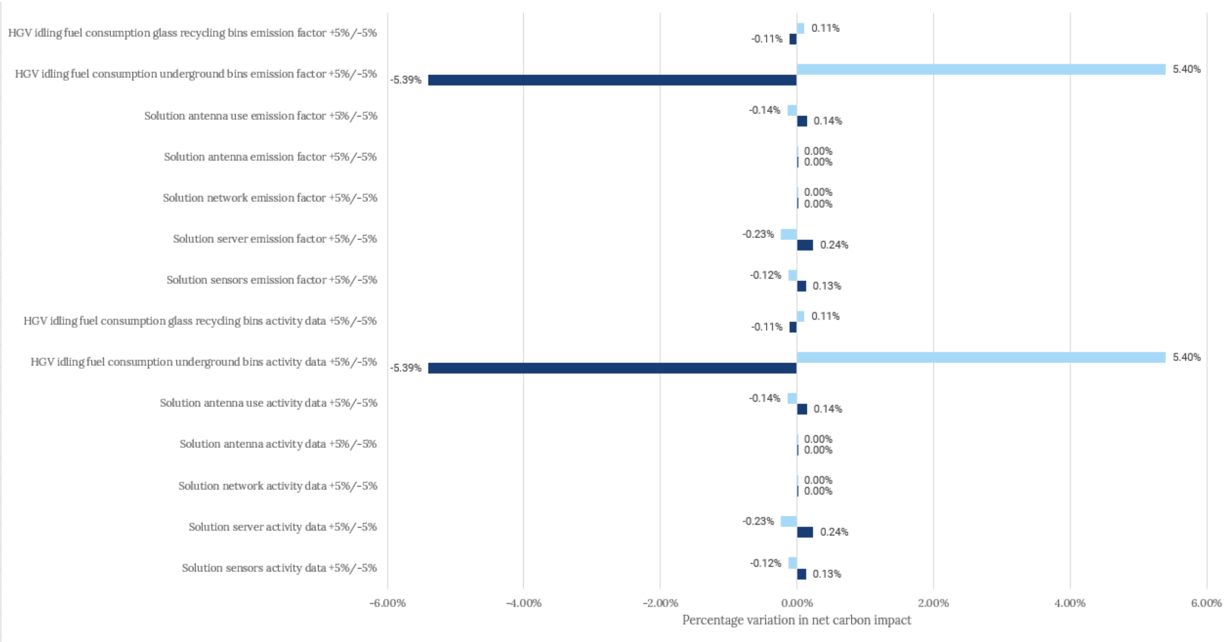
The sensitivity analysis shows the impact of varying the inputs to the net impact calculation in different implementation contexts. The activity data of garbage truck idling fuel consumption and diesel emission factor are the most sensitive inputs. When the activity data for the garbage truck idling fuel consumption is varied by -5%, the net carbon impact decreases to 1.82 tCO_2e. Alternatively when the activity data is varied by +5%, the net carbon impact increases to 2.03 tCO_2e. The percentage change of the solution's net carbon impact when varying this parameter is -5.39% and 5.40% respectively.



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

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The qualitative uncertainty analysis assesses the quality of the data inputs. It demonstrated the assessments' 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 fuel data and make it specific to the activity, by collecting primary data on the garbage truck idling fuel consumption when collecting bins.

			Qualitative Assessment of Data Quality				
Data type	Impact effect	Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity Data	1st order	Solution sensors	Very Good	Very Good	Very Good	Very Good	Very Good
	1st order	Solution server	Very good	Fair	Good	Fair	Fair
	1st order	Solution network	Fair	Fair	Good	Fair	Fair
	1st order	Solution antenna	Good	Fair	Good	Fair	Fair
	1st order	Solution antenna use	Fair	Fair	Fair	Fair	Fair
	2nd order	HGV idling fuel consumption underground	Poor	Fair	Fair	Fair	Fair
	2nd order	HGV idling fuel consumption glass recycling	Poor	Fair	Fair	Fair	Fair
Emission factors	1st order	Solution sensors	Good	Good	Good	Fair	Good
	1st order	Solution server	Fair	Good	Good	Good	Good
	1st order	Solution network	Good	Good	Good	Good	Good
	1st order	Solution antenna	Fair	Fair	Good	Fair	Good
	1st order	Solution antenna use	Good	Good	Good	Good	Good
	2nd order	HGV idling fuel consumption underground	Good	Very Good	Good	Very Good	Good
	2nd order	HGV idling fuel consumption glass recycling	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

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.

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The assessment should be reviewed annually given the needed improvements in data quality and the sensitivity of the results to the activity data of idling fuel consumption and diesel emission factor.

Other considerations for a net carbon impact assessment

Do No Significant Harm

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The solution is not expected to cause significant harm in other ESG areas. It strongly supports objective 1: Climate change mitigation. The smart waste management solution is scalable, while also having the potential to improve communities' quality of life through vehicle pollution reduction.

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.

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

- **Fuel type of trucks –** if the solution was applied in a different garbage truck fleet, it is also likely that the fleet consists of trucks with different fuel types. the trucks currently assessed are diesel vehicles. As vehicles reach their end-of-life or end of lease date, they may be replaced for vehicles with a different fuel type. Given the policies to end the sale of CO_2 emitting vehicles across Europe, it is likely that in the future vehicles will be replaced by zero emission vehicles like EVs. 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.

- **Waste weight** – the weight of the waste collected could have an impact on the fuel usage of the vehicles by impacting the weight being collected and transported. If significant changes are expected in the waste weight being collected, this would impact the fuel usage of the vehicles and would therefore require an adjustment. This would not be possible with the data currently available, as it does not include data on tonnes delivered, a new assessment would likely be required.

- **Locations of smart waste management solution deployment** – The location where the solution is based and implemented can impact several different aspects:
    - Fuel efficiency – the impacts of this have been outlined above.
    - Driving conditions – driving in a different country could impact the road conditions, as well as the weather, which can impact the garbage truck driving during waste collections. Based on the data for this assessment, it would not be possible to adjust the assessment for this, so if the changes in driving conditions were significant, a new assessment would need to be carried out for the new implementation context.
    - Network availability – If network availability is poor in an implementation context, the solution may not work properly or insufficiently. If this is the case, a new assessment of the solution in the implementation context would need to be carried out.

- Network and data centre emission intensity – If the network or data centre emission intensity differs significantly in the new implementation context, this could be updated and adjusted in the assessment.
- Grid mix - if the location varies to that of the assessment and implementation context, then the electricity emission factor will need to be adjusted to account for variances in the location's electricity gird mix.

- **Different waste sensor and antenna suppliers** - If the suppliers of the hardware differ in from the implementation context, this may need to be adjusted for in the assessment.
- **Average collection route distance** – the implementation context considers the same overall distance, the difference between the reference scenario and the ICT enabled scenario is the number of stops completed during the collection route.
- **Frequency of collection trips per year –** if the frequency of bin collections changes, this would need to be adjusted.
- **Types of bins and collection stopping time** – the types of bins may vary, which can affect the characteristics of their collection and consequent related emissions. If this is the case, adjustments such as the collection stop time for the type of bin and the percentage split between the different types of bins will be required.
- **Vehicle type and average fuel consumption –** If the vehicles used to carry out the waste collections differ from those in the implementation context in terms of their average idle fuel consumption, an adjustment would be required as it could greatly impact the second order effect and overall carbon impact. For example, it is possible that over time the garbage trucks are replaced with autonomous vehicles. This could further optimise the operation of the garbage trucks and waste collection.
- **Carbon intensity of fuel** – 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 transport 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.

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.

(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.

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

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