EGDC Case study: Smart Waste Management

April 2024

Case Study Methodology

Provided by: Nokia/The Municipality of Nicosia

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, and Sustainable ICT Consulting.

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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1 Introduction

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 on all other sectors.

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. The Coalition recognises the need for science–based methods to estimate the reduction and avoidance of greenhouse gas (GHG) emissions by specific ICT solutions across sectors. This will accelerate the sustainability and circular transitions of these sectors while contributing to an innovative, inclusive, and resilient society.

To support the EGDC, a set of case study calculators are developed to provide a practical example of calculating the net carbon impact of a green digital solution in line with the European Green Digital Coalition (EGDC) methodology. This work aims to support the members of the EGDC with Action 2 of the EGDC Declaration.

This case study methodology accompanies the 'Nokia Smart Cities- Smart Waste Management' case study calculator and provides further details, additional context and transparency around the case study calculator to ensure the outcomes of the case study are interpreted and used correctly.

Disclaimer for European Parliament Pilot Project – European Green Digital Coalition (EGDC) Case Studies

The following disclaimer is intended to provide clarity and context for the case studies prepared as part of the EP Pilot Project, which have showcased the net carbon impact of specific digital solutions using the EGDC ICT Methodology developed during the project:

1. Purpose of the Case Studies:
The case studies served multiple purposes, including:

- **Development of the Methodology:** They contributed to the development of the EGDC ICT Methodology. These case studies were conducted concurrently with the methodology's creation and served as a valuable testing ground for its initial formulation.
- **Application Examples:** They provided practical examples of how the methodology can be applied to real-life use cases. These case studies were essential in demonstrating the practicality and effectiveness of the methodology when applied to concrete situations.
- **Identification of Improvement Areas:** By conducting these case studies, we aimed to highlight parts of the calculation in need of improvement. They shed light on the challenges and limitations inherent in using available data and indicated the necessary steps to move towards best practices in assessing net carbon impacts.

2. Data Quality as a Key Determinant:
It is imperative to emphasize that data quality is a fundamental determinant of the quality and reliability of the case studies. The accuracy and completeness of the data used significantly influence the outcomes and findings of these case studies.
It is essential to acknowledge that the data available for each case study may differ in terms of accuracy, granularity, and coverage. As a result, the case studies may not necessarily represent the best practice application of the EGDC ICT Methodology. Instead, they reflect the application of the methodology at various stages of data availability.

3. Liability for Errors/Omissions:
While reasonable steps have been taken to ensure that the information contained within the case studies is correct, the EGDC gives no warranty and makes no representation as to its accuracy. We accept no liability for any errors or omissions that may be present in the case studies, methodology, or related information. Users and readers are advised to exercise their judgment and seek further clarification if needed, as the information provided may evolve over time and depend on external factors beyond our control.

4. Appropriate Use of the Case Study Calculators:
The case study calculators are intended for educational and informational purposes. They rely on certain assumptions and input data to generate results.
The results of the calculators are specific to the implementation of the ICT solution and may not be representative for other implementation contexts.
As such, it is imperative for users to refrain from directly extrapolating these results to ICT solutions or implementation contexts that may seem conceptually similar.
Instead, users are advised to use the calculators as a means to understand the practical application of the EGDC ICT Methodology, thereby equipping themselves with the knowledge required to develop customized calculators specifically tailored to their unique ICT solutions and implementation circumstances.

In conclusion, these case studies provide valuable insights into the calculation of the net carbon impact of digital solutions through the practical application of the EGDC ICT Methodology. However, it is vital to exercise caution when interpreting the results, considering the variances in data quality and the evolving nature of the methodology. The findings are indicative of the methodology's potential and its room for refinement as we work towards more accurate and comprehensive assessments of net carbon impacts.

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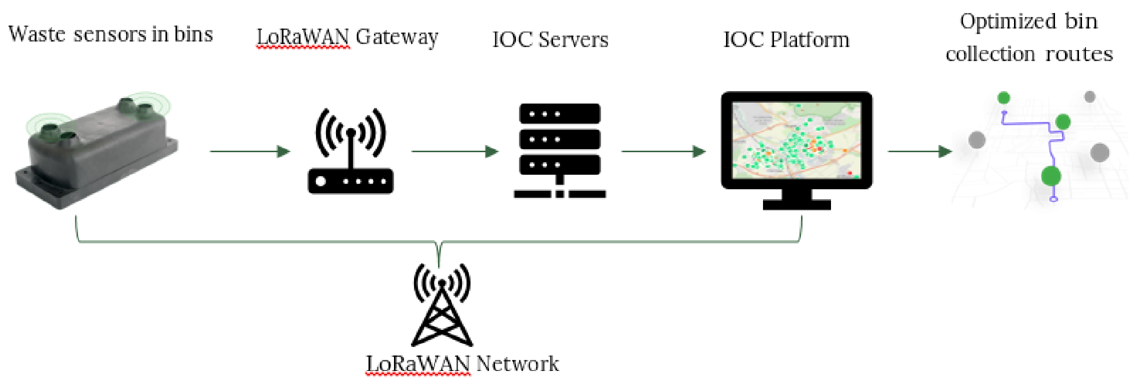
2 Methodology

Smart Waste Management	
Assessment Objective	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. The results of the calculators are specific to the implementation of 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. 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	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 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.

	Limitations include 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. The solution falls under the smart cities sector, as it is a smart waste management solution applicable to communities and cities. The solution was trialled and is currently deployed in the Nicosia municipality in Cyprus. The solution looks to be further developed and deployed across Nicosia in the near future and has potential to be deployed across the country of Cyprus as well as globally due to Nokia's global presence.
Solution Boundary	• **Integrated Operations Centre platform software** • **Waste and IOC servers** • **Smart Sensoneo Quatro sensors** • **LoRaWAN Network*** • **LoRaWAN Antenna (5 dBI Omni Antenna for 863-928 MHz WPAN, LoRaWAN, and ISM)** • LoRaWAN Gateway (Cisco Wireless Gateway for LoRaWAN) • PCs (to access IOC platform) • Garbage truck (HGVs 7.5-15 tonnes) • Underground bins • Glass recycling bins **Components in bold are not in the reference baseline scenario and are therefore in scope for calculating 1st Order Effects.** **Note: Even though the network was existing, the additional data transmission across the network is accounted for.*

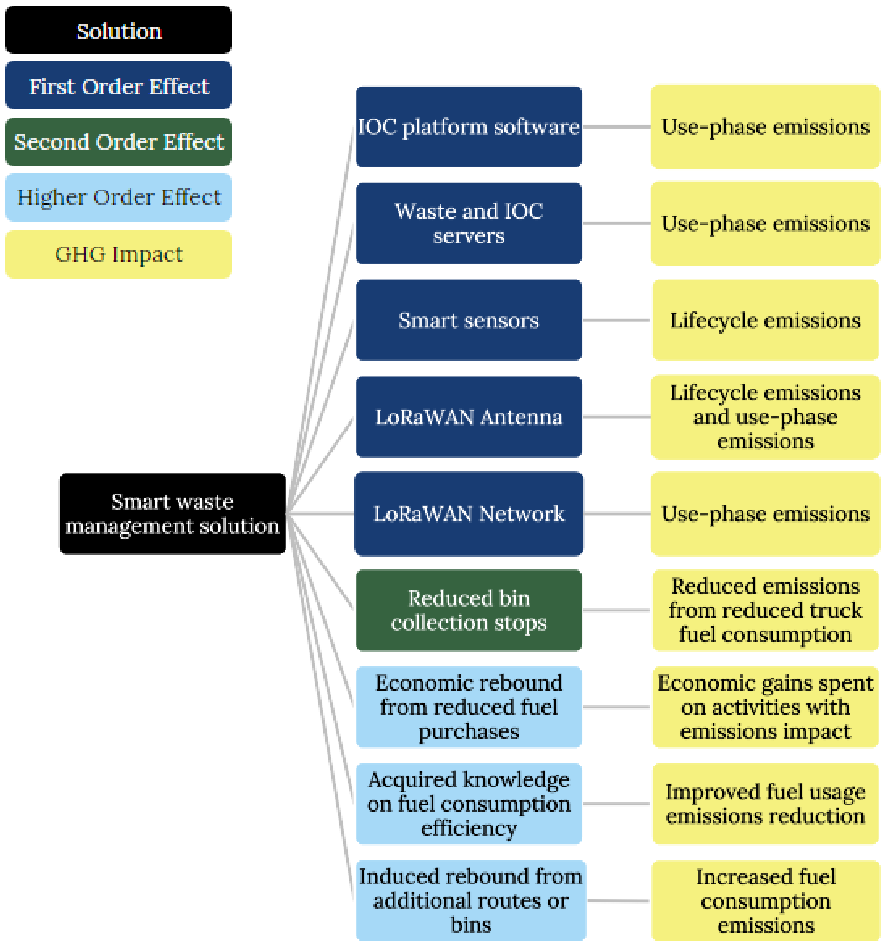
Sensoneo Quatro sensors are placed in bins to detect waste fill level. The sensors transfer this data to the IOC platform and based on the analysis of bin fill levels, collection routes are modified accordingly.



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

Functional Unit	The chosen functional unit is tCO2e 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 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 time boundary is the underground and glass recycling bins collected in 2022. The geographical boundary is the municipality of Nicosia in Cyprus. The solution was implemented across 17 glass recycling bins and 25 underground bins in the municipality of Nicosia's waste management system.
Reference scenario	The reference baseline scenario measures the known number of bins collected in 2022 and collection trip duration prior to the smart waste solution implementation. The baseline is based on data for the full year. In this scenario, garbage truck drivers complete a bin collection route by stopping at each bin to collect the waste no matter the fill level. 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. Data was collected in the Municipality of Nicosia to acquire metrics for each bin type: • Quantity of bins • Collection route stops • Average route length (time) • Frequency of collection trips per year
Description of 1st order effects	• Integrated Operations Centre platform software • Waste and IOC servers • Smart Sensoneo Quatro sensors • LoRaWAN Network – only included electricity usage from the additional data transmission related to the platform accesses across the network • LoRaWAN Antenna (5 dBI Omni Antenna for 863-928 MHz WPAN, LoRaWAN, and ISM)
Categorisation of digital technologies	• IOC platform software (A)

A=ICT Service B=Service specific building block C=Common ICT devices, services, infrastructure	• Waste and IOC servers (C) • Sensoneo quatro sensors (B) • LoRaWAN network (C) • LoRaWAN Gateway (B) • LoRaWAN Antenna (B) • PCs (C)
Description of 2nd order effects	The smart waste sensors and IOC platform that comprise the digital solution allow for the monitoring of waste fill levels of bins in real time. Routes are then adjusted so that the garbage trucks only stop at bins that are >50% of fill capacity, instead of stopping and collecting all the bins as done prior to the implementation of the solution. This optimized routing decreases the number of bin collections stops. Reduced stops lead to time savings and reduced truck fuel consumption when idling during a bin collection stop, which translates to decreased GHG emissions.
Description of higher order effects	There is a potential economic rebound from the spending of any cost savings from the lower fuel consumption and purchase, that is spent on activities that have an emissions impact. Additionally, there is a potential to acquire knowledge of the truck fuel efficiency from the solution's optimised routing which can improve fuel usage in the collection routes, reducing emissions. Improved driver behaviour could, in the long term, lead to vehicles and/or vehicle parts being replaced less frequently, saving GHG emissions from the manufacturing process. These higher order effects have a very low expected magnitude of impact and likelihood of occurrence. Therefore, the positive higher order effect of acquired knowledge is exclude as is the negative higher order effect of an economic rebound. Time savings achieved through the solution are not generating any rebound effects through other activities undertaken by workers once their bin collection routes are finalized.
Mapping of all effects	



Description of calculation	**1st order effects:** 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. **2nd order effects:** 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 (3.032L/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. **Higher order effects:** The assessment of the identified higher order effects concluded they were immaterial due to their expected low magnitude of impact and low likelihood, so they are not included in the calculator. The municipality of Nicosia confirmed that the time saved in bin collection routes does not result in increased emissions from other activities carried out by the garbage trucks or drivers, therefore there is no rebound effect in this use case.
Net Carbon Saving Impact of the Solution	**Total carbon savings impact** Underground bins carbon savings impact: 1.96 tCO2e/year Glass recycling bins carbon savings impact: -0.04 tCO2e/year Total carbon savings impact: 1.92 tCO2e/year

	First order effects impact Underground bins carbon impact: 0.12 tCO2e/year Glass recycling bins carbon impact: 0.08 tCO2e/year **Second order effects impact** Underground bins carbon impact: 2.08 tCO2e/year Glass recycling bins carbon impact: 0.04 tCO2e/year **Savings from reference scenario** Underground bins: 54% reduction of truck idling emissions from decreased fuel consumption Glass recycling bins: 38% reduction of truck idling emissions from decreased fuel consumption. **Savings per functional unit** Underground bins savings per functional unit: 0.078 tCO_2e/bin/year Glass recycling bins savings per functional unit: -0.002 tCO_2e/bin/year
Qualitative data uncertainty and sensitivity analysis	The 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. 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 1.82tCO2e. Alternatively when the activity data is varied by +5%, the net carbon impact increases to 2.03tCO2e. The percentage change of the solution's net carbon impact when varying this parameter is -5.39% and 5.40% respectively. The solution's annual carbon savings impact figure of 1.92tCO2e has a sensitivity of +/- 0.1 tCO2e, when assessing implementation contexts of varying renewables integration. 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

Assumptions	Key assumptions made in the calculations: • Assume sensors are on 24 hours a day, 365 days a year. • Assume the waste and IOC servers consume 40 W per hour in total for the 101 total sensors installed in the Nicosia Municipality. • Assume the extrapolation of the average length of underground bin collection trips from 4 weeks of trial data to one year is reasonable as the trial was carried out in December and less trash is expected in summer months (fewer route stops) while more trash is expected in winter months (more route stops). This is shown by the varying monthly garbage weight data. Therefore, the average duration of the trips will balance out overall throughout the course of the year. • Assume the extrapolation of 2 months' data to one year for the number of extra collection routes of glass recycling bins is reasonable for the same reason as mentioned above. • Assume the Cisco Wireless Gateway for LoRaWAN is already installed and used for other applications, and only the LoRaWAN antenna is installed for the functionality of the smart waste management solution. Assume a single 5 dBI Omni Antenna for 863-928 MHz WPAN, LoRaWAN, and ISM is attached to the existing gateway. Therefore, the additional antenna energy consumption and lifecycle emissions are accounted for in the calculations for this particular smart waste management use case, while the existing gateway emissions are not included. • Assume the IOC platform emissions are immaterial as they represent the running of an application on a computer, specifically the IOC software on the web where the users access the IOC platform. The de minimis impact compared to the total impact of the solution and the lack of primary data on the data transmission energy consumption specific to the platform, justifies its exclusion. • Assume the antenna uses maximum power (10W).
Data sources	Key data sources used in the calculations: • Nokia: EGDC_Smart Nicosia Use Cases(updated).pptx • Nokia: Underground(measurements)25112022-09122022.xlsx • Nokia: Recycle_112022-012023.xlsx • Alternative Fuels Data Center data from the U.S Department of Energy: https://afdc.energy.gov/files/u/publication/hdv_idling_2015.pdf • ER34615 Lithium-thionyl Chloride (Li-SOCl2) Battery weight specifications from: https://www.farnell.com/datasheets/3449642.pdf • UK Government GHG Conversion Factors for Company Reporting 2022: Greenhouse gas reporting: conversion factors 2022 - GOV.UK (www.gov.uk) • ICE Database 2019: Embodied Carbon Footprint Database - Circular Ecology • Carbon Footprint emission factors for life cycle assessments: https://www.carbonfootprint.com/factors.aspx • Carbon Footprint International Electricity Factors: carbonfootprint.com - International Electricity Factors

	• Metric conversion factors: Greenhouse gas reporting: conversion factors 2022 - GOV.UK (www.gov.uk) • Energy consumption per GB transferred: First study on the energy consumption of communications networks | Traficom • Website energy consumption: Internet Data Usage Guide | WhistleOut • Internet data transmission energy consumption: https://onlinelibrary.wiley.com/doi/epdf/10.1111/jiec.12630 • LoRaWAN gateway specifications: Cisco Wireless Gateway for LoRaWAN Data Sheet - Cisco • LoRaWAN antenna specifications: Cisco Industrial Routers and Industrial Wireless Access Points Antenna Guide - Cisco Outdoor 5 dBI Omni Antenna for 863-928 MHz WPAN, LoRaWAN, and ISM (ANT-LPWA-DB-O-N-5) [Cisco 1000 Series Connected Grid Routers] - Cisco
Input adjustments and key considerations for usage of results	Variables to consider if using results in other use cases: • Average collection route distance • Frequency of collection trips per year • Quantity of bins • Types of bins and percentage split • Country selection – emission factors will need adjusting if location is not that of the trial and default in the calculator • Vehicle type and average fuel consumption • Bin collection stopping time
'Do no harm' criteria	Do not foresee any negative impacts on any of the EU Taxonomy's environmental nor social objectives, and 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.
Key areas for improvement	Within the scope of this work, there was no verification of the data undertaken and the calculator is based on the assumption that the data provided by the solution provider is correct. 1. Ideally the trial data for the different bins should cover a full-year's worth of data, or at least 6-months to improve the confidence in extrapolating the raw data. 2. The calculator should seek to include LCAs of the different solution components if they become available. 3. The calculator should be updated with any improvements in data quality around network emissions and IOC platform to try and quantify these emissions as accurately as possible.

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