EGDC Case study: PREDRI

April 2024

Case Study Methodology

Provided by: University of Valencia

EUROPEAN GREEN DIGITAL COALITION

Funded by the European Union

Deliverable name: EGDC Case study: PREDRI

Dissemination Level: Public

Published: April 2024

Developed: December 2023

Prepared by: Deloitte

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

SUB-CONTRACTORS

Carbon Trust

Deloitte

GSMA

Sustainable ICT Consulting

The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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 transition 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 'PREDRI' 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.

2 Methodology

PREDRI	
Assessment Objective	The assessment intent is to understand the net carbon impact of the implementation of the PREDRI solution in the single context of a pilot group of medium sized buses. The assessment is ex-post based on collected data.
Solution Description	*PREDRI - failure PREvention and DRIving optimisation for vehicles* is a fleet management system that leverages on-board monitoring with Artificial Intelligence to optimise routes and encourage efficient and safe driving. Continuous reporting of mechanical parameters helps to anticipate failures and prevent high damage, ultimately extending the life of various mechanical parts. As a result, PREDRI both increases fuel efficiency, and reduces the need to replace exhaustive spare parts. A reduction in fuel consumption saves greenhouse gas emissions that are released during combustion and the reduction in exhaustive spare parts saves greenhouse gas emissions embodied within the materials. The system was developed at the University of Valencia and is running as a pilot study on medium sized buses run by Tours Ejecutivos based in Santiago de Querétaro, Mexico. Currently, data comes from on-board vehicle parameters, routes, and mechanical maintenance which are analysed and returned to the company for daily planning. The system is integrated with spare part storage, refuel gas station, payroll driver rewards and monitoring tools from managerial area for automatic reporting

	and data integration enlarging the set of analysed data. The solution is currently deployed in Mexico on medium sized buses. These buses typically operate on a goo route, with options to divert. They are mainly used to transport private company workers, from factories to areas in the metropolitan area. The solution has indicated that the choice for Mexico was related to the willingness of the company *Tours Ejecutivos* to cooperate and trial PREDRI's methodology. However, the solution has the potential to be deployed across Europe and globally.
Solution Boundary	The following components were listed by PREDRI as contributors to the solution. The provided list included more components, but they were filtered for not being a part of the reference scenario. - Ruptela GPS tracker with 4G mobile communication system and connection to the vehicle control unit (VCU) using CAN, digital and analogue GPIOs - IoT gateway for cloud logging based on IOT gateway for refuelling and spare part stock and repair control - 4 local PCs for administration - Raspberry Pi module for spare part control use and shock - Wialon GPS Platform Server - Google servers

Funded by
the European Union

Functional Unit	The function of the solution is transporting persons. The unit quantity is a transport fleet made up of medium-sized buses. It was considered to set the unit quantity at a singular bus which is more constant across the reference and enabled scenario. However, because a singular bus may only have certain parts replaced every couple of years, it was decided to set the quantity at the entire fleet. Performance for this solution can be defined as a bus driving 100 kilometres. This is because both fuel usage and replacements of mechanical parts logically have a direct and positive relationship with the number of kilometres driven. The unit of 100 kilometres was chosen to allow for a comparison across fleets of different sizes and aligns with the common market practice of measuring fuel efficiency in litres per 100 kilometres.

	However, the decision was made to list the variables of oil consumption and replacements parts as a number or unit per year (rather than as a number or unit per 100km). Similarly, the results show reductions in fuel, oil and replacements parts as a number or unit per year. This was done to make the calculator easier to use, as most fleet operators register their use of fuel, oil, and replacements parts per year. Moreover, it prevents the display of results smaller than 1/100,000 which may be difficult to read. Nevertheless, the results still correlate to the functional unit of kg CO2e / 100km.
Assessment Boundary	From April 2021 until April 2023 measurements included the distance each vehicle drove per day, and the fuel they consumed. Measurements for the changing of tyres, brake pads, and oil were noted from January 2022 until April 2023. This does not match the same timeframe as the data above. It therefore comes with a higher uncertainty and has been scored as “poor”. All data was recorded in Santiago de Querétaro, Mexico and analysed by PREDRI in Valencia, Spain. The solution is currently deployed in Mexico on medium sized buses. These buses typically operate on a fixed route, with options to divert. They are mainly used to transport private company workers, from factories to areas in the metropolitan area. The solution has indicated that the choice for Mexico was related to the willingness of the company *Tours Ejecutivos* to cooperate and trial PREDRI’s methodology. However, the solution has the potential to be deployed across Europe and globally.
Reference scenario	The reference scenario is a fleet of 85 medium-sized buses operating in Mexico. They hold 20 to 40 persons per bus and drive on diesel. It is not clear if there was any other optimisation system in use in the reference scenario, but it may be assumed software like Google Maps routing was used.

Funded by
the European Union

As data collection started as the same time of the implementation of the solution, the reference scenario includes the early period of the implementation of the solution. Ideally, measurements for the reference scenario would be taken before the implementation of the solution but this approach was prevented due to a lack of data. PREDRI developers stated that the solution needs a long time to start functioning.

Whilst the overall fleet consisted of 214 buses, most had to be eliminated from the dataset. First, many bused did not register any distance driven or fuel consumed. Second, some buses registered extreme fuel consumption relative to the distance driven. For instance, according to the data provided, bus ID#3 in 2021 drove 18 kilometres, whilst consuming 170 litres of diesel in the same year. The final 14 buses were eliminated from the dataset because they did not drive in all monitored months. These were excluded to ensure the same fleet is compared throughout the years, avoiding the possibility of comparing more efficient buses with less efficient buses.

From April 2021 until April 2023 measurements included the distance each vehicle drove per day, and the fuel they consumed, measured at the moment they filled up their tank. Over the 2 years, the overall data includes:

- 14.6mn kilometres driven
- 2.6mn litres of diesel consumed

Additional measurements included the changing of tyres, brake pads, and oil. These were measured from January 2022 until April 2023 and noted down per day. Over the 14 months, 15 vehicles had spare parts replaced. The total number of replacements in the data includes:

- 77 tyres
- 81 brake pads
- 2500 litres of oil (mainly engine oil, but also braking pump oil and gearbox oil – these are measured together).

The solution also provided data on filter and car battery replacements. Over the period the number of filters stayed constant and was thus not added to the calculator. The number of datapoints for car battery replacements was not sufficient to include into the dataset. All numbers related to spare part

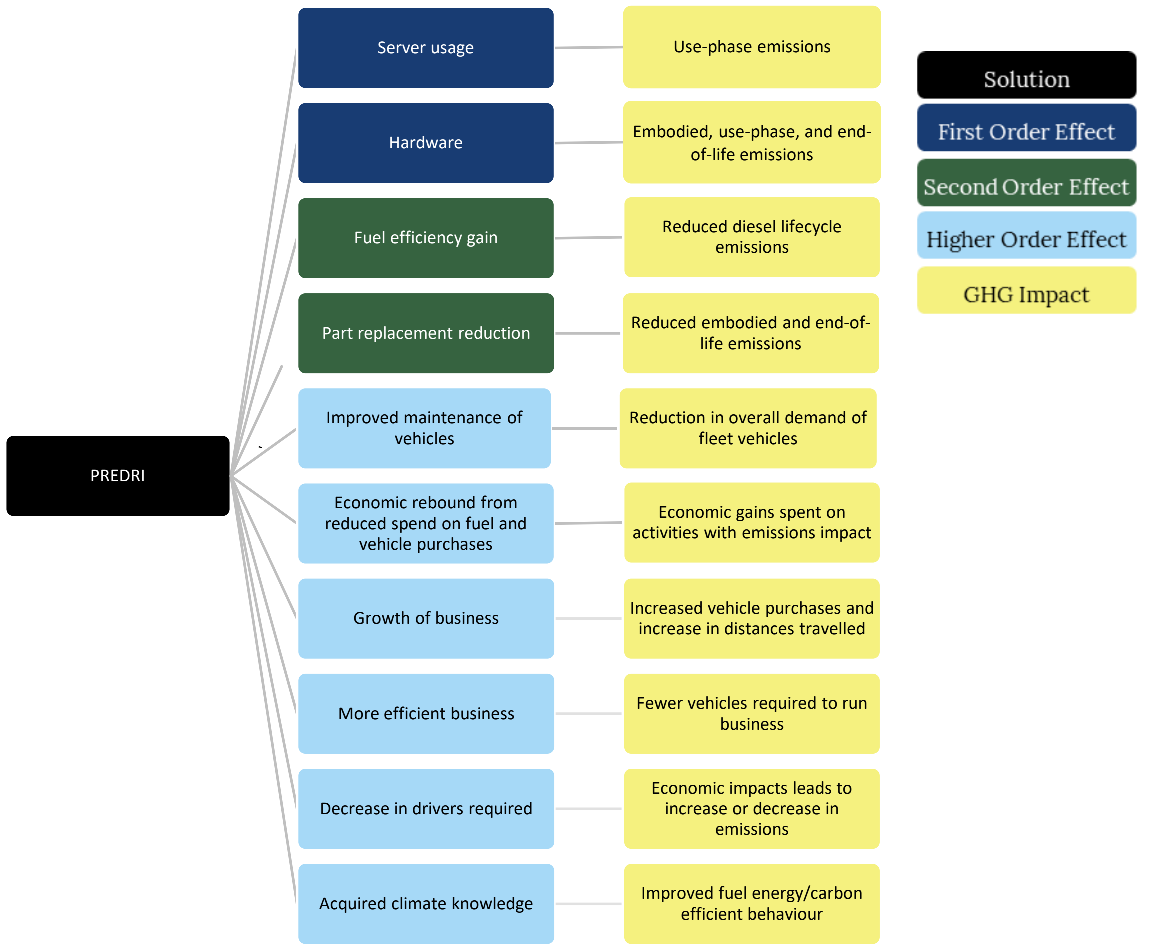
	replacements come with uncertainties around them as there was limited data available. The solution estimates data on spare part replacements will be more reliable from 2024 onwards. For some spare parts, there was some data from 2021. However, due to issues with starting up the system, and scaling up, this data was not deemed reliable enough and was excluded from the data analysis. The data ranges were chosen to reflect the update to the system whereby telemetry and driving monitoring evaluation algorithms started working. It is also the data that was readily exportable.
Description of 1st order effects	The first order emissions include emissions related to the production, use and disposal of the GPS 4G module, the use of 4 local PCs, and the use of two servers, owned by Google and Wialon. PREDRI indicated the presence of two more devices that are used for the solution but are not present in the reference scenario, viz. an IoT Gateway device and a Raspberry Pi 4 module. These have a power consumption of 2.4 Watts and 1 Watt, respectively. Their weight is unknown, but they will not weigh more than a couple of kilogrammes. As visualised in the calculator, the emissions related to these devices do not meet the 5% materiality threshold and have therefore been excluded. The GPS4 module also doesn't meet the materiality threshold but as its weight is known, it has been kept in for illustrative purposes. For the PCs, whilst their energy consumption is used in the calculation, they can be justified to exist without the solution being implemented. Therefore, the embodied and end-of-life emissions can be excluded as these can be considered to have already occurred. The data centres used to host the server capacity can also be justified to exist without the solution being implemented. Their embodied and end-of-life emissions have also been excluded. As it is assumed another optimisation system like Google Maps was used, network emissions are assumed to be the same across the reference

	scenario and implementation scenario and have been excluded from the calculation.
Categorisation of digital technologies A=ICT Service B=Service specific building block C=Common ICT devices, services, infrastructure	The components in the implementation scenario can be categorised as follows. **B** - Ruptela GPS tracker with 4G mobile communication system and connection to the vehicle control unit (VCU) using CAN, digital and analogue GPIOs - Wialon GPS Platform Server and 4G connection - IoT gateway for cloud logging based on IOT gateway for refuelling and spare part stock and repair control - Raspberry Pi module for spare part control use and shock **C** - Google servers - 4 local PCs for administration
Description of 2nd order effects	Through AI-powered driving monitoring and optimisation, the solution firstly improves fuel efficiency. This reduces the amount of fuel required to operate the fleet, reducing GHG emissions. Most of the carbon savings are achieved through this mechanism. Secondly, through on-board monitoring of mechanical parts, PREDRI allows for more accurate insight into the health of certain exhaustive parts. This allows the fleet to only replace these parts when necessary. Over the medium to long term, this reduces the overall number of replacement parts that are needed to be manufactured. The embodied emissions that are saved in the process reduce GHG emissions. There is very limited data on end-of-life emissions for tyres and wheel-to-well emissions for oil. As these are positive second order effects, the emission factors for these two processes have been excluded adopting a conservative approach. The conversion factor for brake pads includes the full lifecycle emissions and therefore has end-of-life emissions included. It is important to note that increased fuel efficiency also reduces fine particle pollution. Moreover, used

	tyres may also emit fewer fine particles than new tyres (Emissions Analytics, 2020). However, as the calculator focuses on GHG emissions, these considerations have not been included into the calculations.
Description of higher order effects	PREDRI's effect on driving behaviour, as well as the more precise monitoring of replacement parts may mean that in the long term, vehicles themselves (rather than the parts in them) can be replaced less frequently. On a system-level this could reduce the demand to produce new vehicles, saving GHG emissions during the manufacturing process. An optimisation of vehicle fleet can also result in an increase in operations and distance travelled. Reduced spend on new vehicles and fuel can cause an economic rebound effect as financial capital can be reallocated to activities that reduce or increase carbon emissions. A more efficient fleet in terms of fuel and spare part replacements may also allow a company to increase its profit margins and grow, thus increasing the number of vehicles on the roads emitting more GHGs. Alternatively, improved efficiencies may allow the business to operate with fewer vehicles. Another higher order effect results from the decrease of drivers needed. The economic impacts associated with the lower income of these drivers could lead to an increase or decrease in GHG emissions. The reduction in costs of delivering products and the associated economic impacts could lead to an increase or decrease in GHG emissions. Finally, the acquired knowledge of climate and fuel efficiency can improve fuel usage in other areas, reducing emissions. These higher order effects are excluded as there is a high uncertainty around their impact, there is a relatively weak claim to causality, and there is very little data availability.

Funded by
the European Union

Mapping of all effects



Description of calculation	**First order effects:** Embodied emissions of the GPS 4 module are calculated by multiplying the weight of each module with the number of vehicles in the fleet and the production carbon conversion factor to obtain GHG emissions. Additionally, a conversion factor for end-of-life is used. Taking a conservative approach, it is assumed the device ends up in landfill. Emissions related to energy consumption of the GPS 4 module and the 4 local PCs are calculated by multiplying their power consumption with the Mexican electricity grid emission factor to obtain GHG emissions. Emissions related to the use of servers is estimated by multiplying the spend on server usage with the

	relevant carbon conversion factor to obtain GHG emissions (see the sections on assumptions and key areas for improvement for the relevant caveats and limitations). **Second order effects:** The new fuel efficiency is calculated by multiplying the selected fuel efficiency before the solution with the reduction factor obtained from the solution's data. Given the irregularities in the data, the reduction factor was approximated using a trendline. This is multiplied with the overall distance driven by the fleet to obtain the reduction in fuel usage, which is multiplied with the carbon conversion factor for diesel to obtain saved GHG emissions. For the reduction in spare parts and oil, similar calculations are performed. Default turnover of parts is calculated using the percentage of replacements from the solution per kilometre driven. The respective reduction factors were obtained by dividing the number of replacements (or litres of oil) over the total distance driven by the entire fleet that year, and comparing the data from 2022 with the data from 2023. The selected turnover of parts is multiplied with the respective reduction factor and with the relevant carbon conversion factor to obtain saved GHG emissions. The GHG emissions are deducted from the GHG savings to obtain the amount of overall carbon savings. **Higher order effects:** Due to data limitations, the possible higher order effects of the solution have not been included in the calculation. When the solution scales up, it will be important to measure these. These measurements could include the monitoring of the bus company's growth, and if the company, due to efficiencies, is able to operate with fewer buses.
Net Carbon Saving Impact of the Solution	**For the reference scenario (Tours Ejecutivos' buses), the following carbon reductions were noted:** *Total carbon saving impact: 169 t CO2e / year* *1st Order effects: 2 tCO2e* *2nd Order effects: 171 tCO2e* *Savings from reference scenario: 3.8%*

	Saving per functional unit: 2.2 kg CO2e / 100 km
Qualitative data uncertainty and sensitivity analysis	The overall data quality for first order emissions is good, with relatively precise energy consumption data. The second order emission data quality for fuel consumption is good but it is poor for part replacements. This is because of the limited timeframe for measurements and poor completeness. The sensitivity of specific datapoints to the overall outcome is relatively low. Data related to the 2nd order effects is relatively important in terms of sensitivity, scoring around 5% . 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	Given the limited data used to build this calculator, it is assumed that - The solution is applied to the entire fleet. If only a part of the fleet is optimised through PREDRI, only the data for those should be included into the input adjustments; - Fleet vehicles drive on diesel fuel (given all buses in the dataset drove on diesel); - The data from the Mexican bus company can be extrapolated to European cities. There is currently no reason to assume this would not be the case; - The fleet exists of medium-sized buses (holding 20-40 passengers); - No prior fleet management system was used; - Reductions in fuel and spare parts continuously improve and can be extrapolated to other fleets;

	- Server usage, hardware use and software use stay constant as the fleet scales up; - The GPS 4G modules installed in the vehicles operate 9 hours a day, for 365 days a year. This is an assumption based on assumed working hours of bus drivers; - The 4 local PCs, the IoT gateway, and the Raspberry Pi 4 device operate 18 hours per day, 365 days year. This assumption was made by PREDRI based on current use; - The energy requirements from servers can be estimated through spend using the EEIO database. This comes with certain caveats; - Emissions factors included within the EEIO database are collated from underlying data sourced from multiple sources across multiple years. As a result, there should not be assumed to be perfect comparability between factors. Additionally these factors represent a time lag in their production. In the case of the current set of factors (2020 version), data was assessed to align most closely with 2013 carbon intensity values. Therefore, any changes in carbon intensity of products since 2013 should be assumed not to have been captured within these factors; - Given the data is calculated on a kgCO2e/$(2013) basis, where company spend data from years later than 2013 is used, impacts of inflation have not been accounted for. The anticipated impact of inflation is that emission factors will decline as a result of the purchasing power of $1 being eroded by inflations (i.e. $1 buys less in 2023 compared to 2013, therefore less embodied carbon in the good). As the emission factors are designed to be used for a generic emissions estimation, rather than for accurate and detailed emissions calculation, no corrections have been made as relative emissions intensities of different products are not expected to be materially impacted; - Data calculated is based on US production models. As a result, these may not be reflective of production models outside of the US which could have either higher or

	lower carbon intensity. As the emission factors are designed to be used for a generic emissions estimation, no corrections have been made as the values are to be considered indicative; - Data is calculated based on US production models. No corrections have been made for Purchasing Power Parity (PPP) of products between different countries. This could result in certain product types costing relatively more or less in different countries when compared to the US. In turn, this could impact the emissions factors (where products cost relatively more, emission factors would be lower, and vice versa).

Data sources	The following publicly available sources were consulted to support data provided by PREDRI:
	• The UK government GHG conversion factors from 2023 were used for the conversion of diesel and the lifecycle emissions of oil, tyres, and the GPS 4G module;
	• Gradin & Åström (2020)'s GHG conversion factor for brake pads was used;
	• Data from Carbon Footprint Ltd was used to estimate the GHG emission intensity of the Mexican electricity grid;
	• US Government USEEIO 2020 data was used to estimate emissions related to server usage. This is a highly flawed approach but due to data limitations it was the only way server emissions could be taken into account (see key areas for improvement).
	
	PREDRI provided data:
	• Fuel consumption fleet
	• Distance driven by fleet
	• Part replacement rates
	  ○ Brake pad replacements
	  ○ Oil consumption
	  ○ Tyre replacements
	• Weight GPS 4 module
	• Energy consumption GPS 4 module and 4 local PCs

	• Energy consumption IoT Gateway and Raspberry Pi 4 module (excluded from calculation – see calculator) • Spend in USD on Wialon and Google servers
Input adjustments and key considerations for usage of results	**Required inputs:** • Kilometres driven per fleet per year (NB: only list the number of fleet vehicles that use the solution) • Number of fleet vehicles **Optional Adjustments:** • Fuel efficiency (L / 100km) • Oil consumption (L / year) • Brake pad replacements (number / year) • Tyre replacements by fleet (number / year) • The tyre model (with the option of selection three as a % of the fleet). If unknown, a 215/65 R16 tyre is selected, as that was the most commonly used tyre in the reference scenario.
'Do no harm' criteria	The solution is not expected to cause significant harm in other ESG areas. PREDRI's focus on safer driving, as well as its effect on non-GHG emissions (fine particle pollution) mean PREDRI may influence other ESG areas positively.
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 the data provided by the solution is correct. Future calculators for fleet management systems may consider the following improvements. 1. Future calculators should include data on other fuel types, including gasoline and electricity. 2. Data on different journey and vehicle types may improve the reliability of the calculator and broaden its usability. Data on some vehicle types was provided but this was not granular or reliable enough to include into the calculator. Provisional qualitative research by the solution indicates driving

Funded by
the European Union

	style may be more of a determinant than vehicle type. 3. Data from other countries, particularly in Europe, would increase the usability for European and global use-cases. This would also allow for the controlling of country-specific variables, such as infrastructure. 4. The limited data for this solution does not allow for an analysis of when the AI has effectively optimised the fleet, i.e. whether this has already happened within the trial period or whether the point of optimisation is still to reach. 5. The data provided for this calculator showed various fluctuations in efficiencies. This may point to measurement errors. A larger dataset would allow for the smoothing out of these irregularities better. According to the solution, data on spare parts replacements will be more robust from 2024 onwards (due to logistical issues with starting and scaling measurements). 6. Given this solution is AI-run, for future calculators it would be valuable to have better data on the first order emissions related to server usage. A best-case scenario would include more direct measurements of server usage. For this calculator, however, there was extremely limited data on server usage. The server providers used for the solution do not disclose the related emissions, nor what electricity grid they are connected to, or the vCPU required. As a last resort the method based on spend was used. 7. Future calculators may include a baseline scenario whereby the fleet is already (partly) optimised to increase its usability for a wider range of baseline scenarios and fleets. 8. Due to lockdown restrictions related to the COVID-19 pandemic, some of the data may not wholly reflect the solution's carbon impact. Future calculators should try to avoid including measuring during lockdowns. 9. Future calculators should include lifecycle analyses of the hardware used, for which there was no data available. Similarly, the emissions related to the transport of the

	hardware could not reliably be estimated for this calculator. 10. Future calculators can include more spare part variables.

Funded by
the European Union