EGDC Case study: Dynamic Line Rating Platform

April 2024

Case Study Methodology

Provided by: Telefónica/Red Eléctrica de España

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

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European DIGITAL SME Alliance

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Deloitte

GSMA

Sustainable ICT Consulting

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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 'Dynamic Line Rating Platform' 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.

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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.

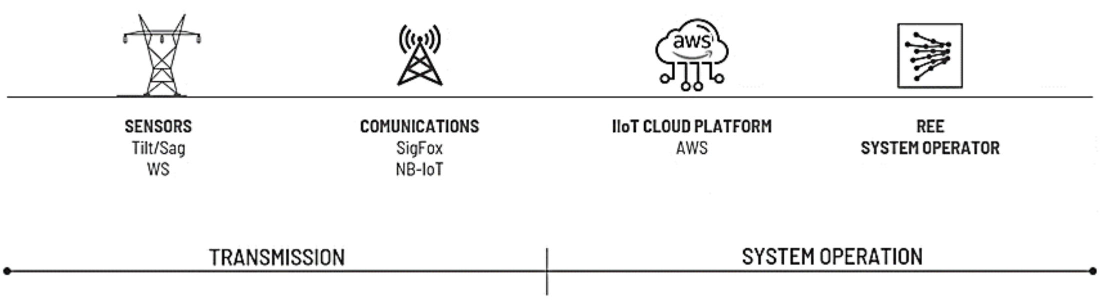
In conclusion, these case studies provide valuable insights into the calculation of the net carbon impact of digital solutions through the practical application of the EGDC ICT Methodology. However, it is vital to exercise caution when interpreting the results, considering the variances in data quality 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

Dynamic Line Rating Platform	
Assessment Objective	The outputs from the assessment of the Dynamic Line Rating Platform 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 the Dynamic Line Rating Platform solution across a pilot assessment of 533km of 220kV and 400kV lines in mainland Spain. In this specific context, the implementation of the DLR solution has three alternative transformations, the line would have either been uprated, been transitory or had no physical alternative. Each alternative has different carbon savings potential, based on the enabling mechanisms it entails. 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 a year of implementation data for the avoided upratings, and ex-ante when determining the projected effect of renewable integration.
Solution Description	The Dynamic Line Rating (DLR) platform solution aims to optimise the existing electricity transmission grid based on local and remote monitoring and sensors, operating with power carrying capacities calculated in real time. These capacities are calculated using thermal line modelling and data obtained from the monitoring of immediate atmospheric conditions and the physical parameters of the installation along its full length. This enables access to power capacity, which would have been blocked for security reasons, due to better knowledge of the lines' real conditions, which also results in safer and more flexible operations. The solution consists of a dynamic line rating system that enables the transmission system operator (TSO) to operate some transmission circuits using real time data and forecasts. The system includes conductor sensors and local weather stations, IoT communications, a cloud platform and an algorithm that computes the real time thermal rating and forecasts climatic conditions. With this system, the TSO can make use of the idle capacity that already exists in the lines but that is inaccessible

	when using seasonal ratings. The deployment of the DLR system is much easier and faster than other projects intended to enable uprating the transmission lines. It can avoid adverse environmental impacts such as the manufacturing of steel structures, the use of large cranes and the corresponding emissions. Additionally, DLR can increase the capacity of the network to integrate renewable energy into the electricity transmission grid. This case study aims to quantify the solution's carbon impact of integrating renewable energy into the electricity grid and replacing the line uprating that could have happened in its absence. The solution falls under the energy and power sector, as it targets transmission systems.

Solution Boundary	Digital components
	• **Weather stations**
	    ○ **Wind sensor**
	    ○ **Temperature sensor**
	    ○ **Solar radiation sensor**
	    ○ **Datalogger**
	• **Conductor sensor**
	• **AWS cloud platform**
	• **DLR platform and software**
	• **4G/5G telecommunications network** (accesses for DLR system)
	• PCs (to access DLR Platform)
	
	Non-digital components
	• Transmission network infrastructure (lines, towers)
	
	Components in bold are not in the reference scenario and are therefore in scope for calculating 1st Order Effects.



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Functional Unit	The chosen functional unit is tCO_2e per kilometre of transmission line in mainland Spain per year. The unit per km of line was chosen to allow for the comparison between different line types, lengths, and reference scenarios. The reference scenario, line length and type directly impact the emissions related to the solution. The reference scenario dictates what the alternative line transformation would have been, and the carbon-emitting activities involved. Additionally, the components needed for the solution's installation vary based on the type of line. The solution is also installed on a 'per km' basis and therefore the quantity of components that make up the solution, and their first order effect, are directly linked to the lines' length. The tons of CO_2 equivalent per km of transmission line is considered an adequate functional unit as the number of kms remains the same across the reference scenario and ICT enabled scenario when assessed. The savings also change proportionally as the number of kms of line changes.
Assessment Boundary	The time boundary for the assessment is the year 2022 for the ex-post assessment and the year 2026 for the ex-ante assessment of the renewable integration. The geographical boundary is mainland Spain. The solution is pre-commercial and has been deployed across 20 circuits in mainland Spain. The case study analyses 13 of these mainland circuits due to data availability and accessibility. The solution has the potential to be deployed extensively across Spain as well as internationally by different system operators. The context in which the solution is implemented are circuits where seasonal ratings are used to manage lines' power capacity as there is no detailed, real-time data on power lines' actual conditions to manage and optimise operations.
Reference scenario	There are three reference scenarios for the implementation of the DLR solution. The reference scenarios reflect the alternative transformation that existing lines in the pilot assessment would have undergone if the DLR solution would not have been implemented. These alternatives, and their percentage split, are known and were provided by Red Eléctrica de España (REE) who implements the solution across its transmissions system. **Ref. Scenario I – Uprating alternative**

	The first reference scenario is the uprating of a 220kV or a 400kV transmission line. Line uprating involves modifying an electrical line's characteristics for the purpose of, for example, increasing its electrical capacity. It involves the construction and implementation of new infrastructure and materials, such as steel and concrete, to reinforce and support the line's new electrical characteristics. Based on the lines in the assessment, 2% of the kilometres under study would have been uprated. **Ref. Scenario II – No physical alternative** The second reference scenario is DLR having no physical alternative. In this case the lines would have not undergone any type of transformation. Based on the lines in the assessment, 65% of the kilometres under study had no physical alternative. **Ref. Scenario III – Transition alternative** The third reference scenario is a transition alternative in which DLR is implemented for an average of three years, and then the line is uprated. Based on the lines in the assessment, 33% of the kilometres under study have a transition alternative. In the reference scenarios, seasonal ratings are used to manage lines' power capacity as there is no detailed, real-time data on power lines' actual conditions to manage and optimise operations.

Description of 1st order effects	• Weather stations
	  ○ Wind sensor
	  ○ Temperature sensor
	  ○ Solar radiation sensor
	  ○ Datalogger
	• Conductor sensor
	• AWS cloud platform
	• DLR platform and software
	• 4G/5G telecommunications network (accesses for DLR system) – only included electricity usage from the additional data transmission related to the platform accesses across the network

Categorisation of digital technologies
 	
A=ICT Service
 	
B=Service specific building block
 	
C=Common ICT devices, services, infrastructure
	• Weather stations
	  ○ Wind sensor (B)
	  ○ Temperature sensor (B)
	  ○ Solar radiation sensor (B)
	  ○ Smart Spot Core/Datalogger sensor (A) – the principal system used to collect, communicate and integrate data with Red Eléctrica de España (REE)
	• Conductor sensor (B)
	• AWS cloud (C)

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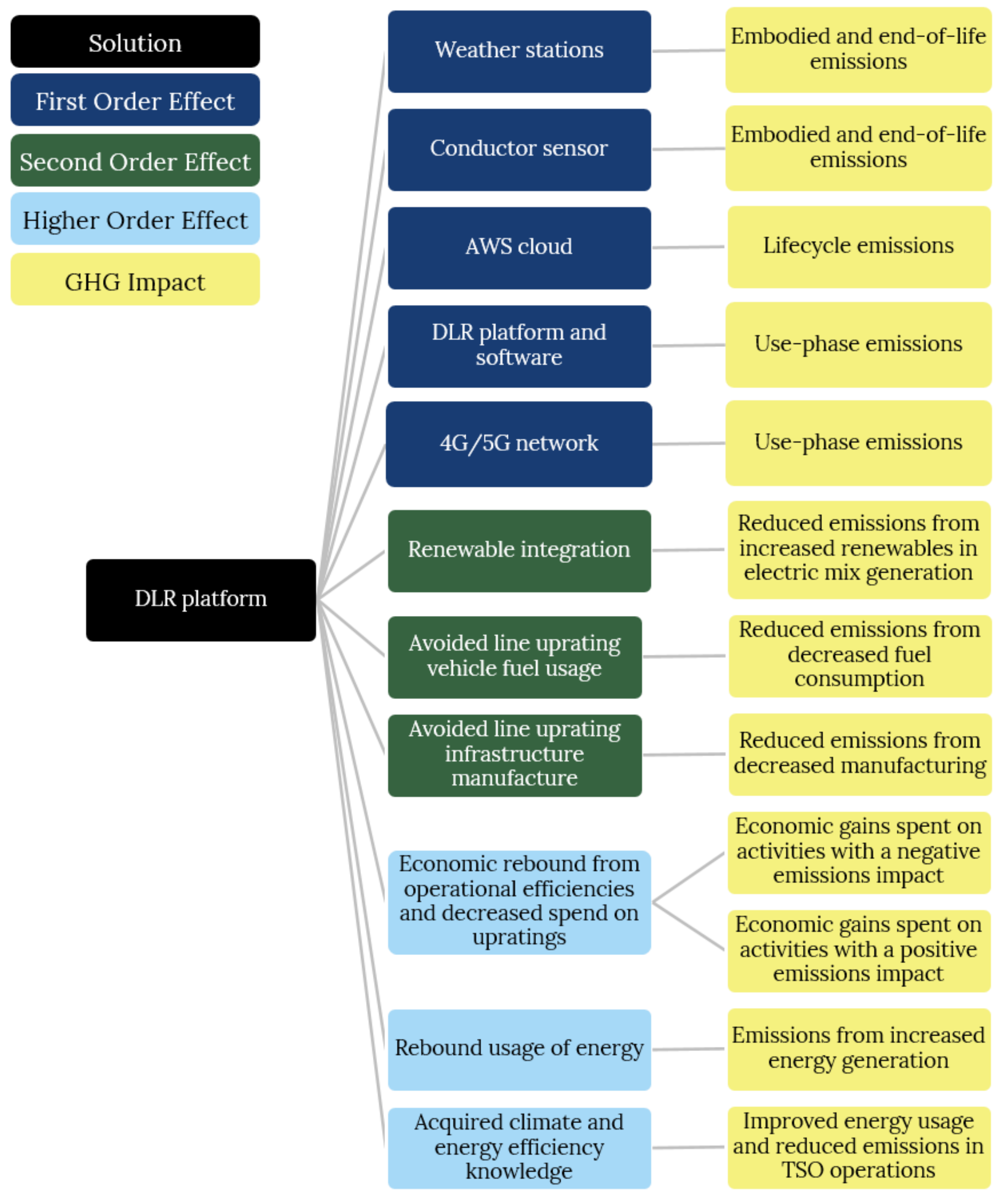
	• DLR platform and software (A) • 4G/5G telecommunications network (C)
Description of 2nd order effects	**Renewable Integration** The DLR platform allows for the real-time monitoring of climatic conditions based on physical parameters which then feed into the calculation of the line's thermal limit. While lines' electrical capacity is typically based on seasonal ratings, the improved knowledge and accuracy of calculations can enable access to a greater circuit capacity and a greater amount of renewable sourced energy to be transmitted through the grid. This ultimately improves decarbonisation of the electric system, reducing renewable spillage. Red Eléctrica de España has evaluated the renewable integration and derived emission reduction in the Spanish electric system using ENTSO-E CBA 2.025 methodology approved by the European Commission in 2018 after public consultation. **Avoided Line Uprating** The DLR solution can also be implemented in circuits which would have alternatively been uprated to increase their power carrying capacity. Uprating consists of carbon-intensive activities such as establishing a concrete foundation and building steel infrastructure. These materials as well as the fuel consumption from cranes and other necessary vehicles are therefore avoided as the DLR solution substitutes the need for uprating the lines.
Description of higher order effects	A potential higher order effect is the increased use of energy if it is perceived as renewably sourced. Though the solution can decarbonise the electric system through the maximisation of renewable integration, some energy sources in Spain's grid mix still emit emissions. As this higher order effect is improbable and difficult to quantify, it has been identified and assessed qualitatively. There is a potential economic rebound for final customers as economic savings due to direct cost savings from the avoided uprating installation and manufacturing costs may be used for carbon emitting or saving activities. This potential higher order effect is difficult to demonstrate and quantify, therefore it was acknowledged and assessed qualitatively. Acquired knowledge on the climate and energy efficient technologies can improve energy usage of existing infrastructure power line capacity as well as other operational areas of the TSO or of the whole electric system, reducing overall emissions. As this potential higher order effect is expected to have a low

	magnitude of impact and is difficult to quantify, it has been identified and assessed qualitatively.

Mapping of all effects



Description of calculation	**1st order effects** The first order effects calculation captures the lifecycle emissions of the weather station sensors and conductor sensor that were installed for the use of the digital solution. For the conductor sensor (inclinometer), and weather stations which comprise a data logger, wind sensor, solar radiation sensor and temperature

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	sensor, the embodied and end-of-life emissions were calculated according to the weight and material composition of the component. For each component material, the weight of the material was multiplied by the appropriate emissions factor to obtain its embodied emissions. Then, a disposal emission factor was multiplied by the material weight to get the end-of-life emissions. The sum of the embodied and end-of-life emissions results in the total lifetime emissions of the material, and the sum of all the materials' lifetime emissions equals the components' lifetime emissions. This was divided by the sensor lifetime to obtain a "per year" impact. The datalogger powers all the weather station components and is solar and battery powered, while the conductor sensor has an inductive energy harvester, therefore there are no use-phase emissions for these components. As the datalogger is battery-powered, the battery's lifecycle emissions were calculated separately as an annual figure, as its lifetime differed from that of the logger, and then added to the logger's annual impact. The number of conductor sensors and weather stations per km of line was provided, so their annual emissions impact was multiplied by their respective quantity per km and by the total length of line in the assessment to reflect their total first order effect. The first order effect also includes the emissions arising from the solution's data transmission on the 4G/5G network provided by Telefónica. The annual lifecycle emissions per access, from Telefónica*'s Connectivity solutions: Life Cycle Assessment Executive Report* were multiplied by the number of weather stations to obtain the network annual emissions. The sum of the components' annual emissions and the network annual emissions make up the solution's annual emissions. There are several elements excluded from the solutions emissions due to lack of data availability, which were addressed through materiality assessments to justify their exclusion from the calculation. A materiality assessment was carried out for the DLR platform user-interface energy consumption. The overall impact of a user accessing the platform was estimated to be immaterial, accounting for 0.0001% of the annual net GHG savings impact. Similarly, the materiality of the AWS cloud platform, on which the solution is hosted, was assessed using secondary cloud lifecycle data of AWS. To be conservative, the data used assumes AWS runs at 100%, on the highest CO2e workload, as no insight was available on AWS actual workload for the solution. This resulted in a 0.0006% impact.

	Red Eléctrica de España confirmed that the installation of the DLR solution is simple and happens once. It involves travel of workers by cars and the use of typical tools to install the solution's components. It is assumed the transportation of the DLR solution components (sensors) and their installation has a negligible carbon impact and is therefore excluded. The sum of all the variables assessed for their materiality equates to 0.05% of the solution's annual net avoided emissions. The 5% materiality threshold for exclusions in the methodology, when applied to the net carbon savings of the 13 lines assessed in the case study, amounts to 2,504,657 kgCO2e. The first order effects excluded amount to 303.4 kgCO2e. Therefore, since the sum of the impact of the assessed variables falls below the 5% exclusion threshold set out in the methodology, the DLR platform use-phase emissions and cloud emissions were not included in the solution's calculations. **2nd order effects** The second order effects calculation captures CO2e savings achieved through increasing transmission line capacity, but these are dependent on the reference scenario. The percentage occurrence of each alternative is multiplied by the total length of line (kilometres) to allocate the kilometres between the reference scenarios and calculate the emissions savings achieved in each scenario. **Ref. Scenario I – Uprating alternative** The second order effects calculation for Ref Scenario I captures CO2e savings achieved through optimising transmission line capacity to avoid line upratings which involve manufacturing materials and vehicle fuel consumption. The second order effect from uprating lines is the avoided emissions associated with the construction and implementation of the alternative DLR solution. The steel and concrete volume required per line uprating is multiplied by the relevant lifecycle emission factor to get the infrastructure emissions. Uprating emissions related to crane and truck use are calculated based on fuel consumption and hours of use, by applying the diesel emission factor. The sum of both the fuel emissions and infrastructure emissions represent the avoided emissions from not uprating a line. As these emissions vary based on the type of line, the calculations for the 400kV line and 220kV line are carried out separately but follow the same approach. The avoided uprating emissions are multiplied by the kilometres of line which would have been uprated and then divided by 20 years, the average line uprating lifetime, to obtain the annual avoided uprating emissions.

	Ref. Scenario II – No physical alternative The second order effects calculation for Ref Scenario II captures CO2e savings achieved through optimising transmission line capacity to increase renewable integration into the grid. The savings are a result of increased capacity, and a change in the emissions intensity of the electric system due to an increase in renewable integration and a decrease of conventional generation production. To calculate the carbon saving from the solution for Ref. Scenario II, the calculator measures the difference in the Spanish Electricity Generation Mix with and without DLR. This is calculated for a year by REE using Plexos modelling software that accounts for expected grid changes, using the ENTSO-E CBA 2.025 methodology approved by the European Commission in 2018 after public consultation. A weighted average emissions factor of the energy sources, covering generation and well-to-tank emissions, is multiplied by the electricity generation (in kWh) with and without DLR to obtain the emissions from electricity generation. The difference in emissions between the grid with and without DLR equals the carbon savings from renewable integration. REE explained that changes in the capacity of the grid, specifically drops in carbon-intensive energy sources, are exclusively due to increases in the generation of renewable sourced energy. The annual avoided emissions from renewable integration are divided by the kilometres of line in the assessment to get the saving (kgCO2e) per km. This is multiplied by the kilometres with no physical alternative to obtain the annual avoided emissions from this reference scenario. **Ref. Scenario III – Transition alternative** The second order effects calculation for Ref Scenario III captures CO2e savings achieved through optimising transmission line capacity to increase renewable integration into the grid during the time when line uprating is delayed. Similar to Ref. Scenario II, the annual emissions savings from renewable integration per kilometre of line are multiplied by the kilometres of line whose alternative was a transition. Then, these carbon savings are multiplied by the average DLR transitory period of three years, which represent the average number of years DLR delays the line uprating, to get the lifetime avoided emissions from renewable integration in the transition alternative scenario. To derive the annual avoided emissions, the lifetime figure is divided by the transition lifetime of 23 years. **Higher order effects**

	The qualitative assessment of the identified higher order effects concluded their magnitude of impact ranged from medium to low and overall had a low likelihood of occurrence. However, the higher order effects identified were not assessed quantitively, mainly due to the lack of data and the consequent uncertainty around their calculation. **Net GHG impact calculation:** The net GHG impact is calculated per reference scenario by subtracting the first order effects from the reference scenario's annual avoided emissions. The first order effects are apportioned based on the percentage of kilometres of line of each alternative. Each reference scenario's annual avoided emissions are divided by the kilometres of line corresponding to each alternative. Dividing the net annual carbon impact of each scenario by their corresponding kilometres of line derives the net avoided emissions per kilometre of line. The overall avoided emissions enabled by the solution are the sum of the avoided emissions from renewable integration for the lines with no physical alternative and transition alternatives and the avoided uprating emissions of both types of lines. To obtain the total net avoided emissions, the first order effects calculated for both types of lines are subtracted from the total avoided emissions. The overall net avoided emissions per km of line is the weighted sum of the reference scenarios' net avoided emissions per kilometre. This per kilometre weighting is done to reflect the proportional impact of each scenario on the total line length. All the calculations are done on an annual basis, so the net carbon impact derived is a yearly figure. This provides greater comparability amongst the alternatives which have varying asset lifetimes, as it takes a lifecycle lens through which to analyse the DLR solution's impact.
Net Carbon Saving Impact of the Solution	Total annual carbon saving impact: 50,094 tCO2e / year First order effects carbon impact: 0.094 tCO2e / year Second order effects carbon impact: 50,094 tCO2e/ year Annual carbon saving per functional unit: 94 tCO2e / km of line / year

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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, ideally looking to collect primary data on the truck and crane fuel consumption. The sensitivity analysis shows the impact of varying the inputs to the net impact calculation in different implementation contexts. The activity data of the renewable integration in the electricity generation and Spain's electricity weighted emission factor are the most sensitive inputs. When the activity data for the renewable integration is varied by -5%, the net carbon impact decreases to 47,589tCO_2e. Alternatively when the activity data is varied by +5%, the net carbon impact increases to 52,598tCO_2e. The percentage change of the solution's net carbon impact when varying this parameter is -5.00% and 5.00% respectively. The solution's annual carbon savings impact figure of 50,094 tCO_2e has a sensitivity of +/- 2,505 tCO_2e, 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	• For the conductor sensor, assume a 50/50 split between electronic components and stainless steel hardware, and that the epoxy encapuslants are made up of AL203 instead of SI02 to be conservative. • Assume the disposal emissions of the materials that make up the conductor sensor are open-loop where the emission factor is available. • Assume the End-of-life fate for all the weather station components, namely the data logger, wind sensor, solar sensor and temperature sensor, is landfill. • For the data logger, assume that besides the battery and solar panel the rest of the data logger is aluminium. • For the solar radiation sensor, assume weight besides the bolts is split equally between the aluminium, plastic and glass components. • Assume the solar sensor uses bolts the same dimension as a 20mm M5 m.s. hex half thread bolts with nuts.

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	• Assume the temperature sensor and wind sensor use screws with the same dimensions as a M2 20mm machine screws csk head. • Assume the solar panel material composition is the following: glass 76%, plastic 10%, aluminium 8%, silicon 5%, copper 1%. • Assume the DLR platform is accessed via a PC and used for 8 hours a day, 365 days a year. This assumption is conservative as all days are considered working days. • Assume the AWS cloud platform runs the DLR solution at 100% workload 24 hours a day, 365 days a year and that the carbon intensity of an instance of a1.medium in eu-west-3 (Europe, Paris) is reflective of the AWS cloud services used for the DLR solution. • Assume the DLR installation is simple and has a negligible carbon impact. • Assume the transportation of the DLR solution components (sensors) has a negligible carbon impact. • Assume the weather stations and its sensors have a 5 year lifetime, and are replaced once during the DLR lifetime of 10 years. • Assume the combined cycle power and the combined heat and power emissions factors provided by REE are lifecycle in scope. • Assume the use of plotdigitizer.com to estimate the numbers on a graphic bar chart provides accurate figures for the calculation of the nuclear energy emissions factor. • Assume an average value for the renewable integration capacity and emissions savings achieved per km of line for 220kV and 400kV lines, based on Red Eléctrica de España's calculations. • Assume all emission factors provided by Red Eléctrica de España, and those obtained from the Association of Issuing Bodies (AIB), are lifecycle emission factors which include well-to-tank emissions and transmission and distribution losses.
Data sources	• Red Eléctrica de España provided the data for Uprating and DLR variables for both a 400kV and 200kV line and the capacity increment due to DLR from their Plexos modelling which simulates Spain's electric generation mix for 2026. • Spain energy generation mix emission factors of combined cycle power and the combined heat and power were provided by Red Eléctrica de España. • Telefónica's Connectivity solutions: Life Cycle Assessment Executive provided the 4G/5G network lifecycle emissions.

	• Telefónica provided the wind sensor, solar sensor and temperature sensors specifications. • Red Eléctrica de España provided the conductor sensor characteristics. • Crane fuel consumption from Liebherr's fuel savings calculator for a Liebherr LR 1200 210000kg crane. • Truck fuel consumption from article from International Cranes and Specialized Transport. • Battery weight from Eco-worthy 30Ah 12.8V Lithium battery specifications. • Screw and Bolt weight from Industrial Tool Agency's weight chart. • Solar panel composition used for the datalogger was retrieved from Greener Ideal. • Data transmission of a website obtained from 'Internet Data Usage Guide' article. • Internet data transmission energy consumption per GB obtained from 'Electricity Intensity of Internet Data Transmission' by J. Aslan et al., 2018. • Internet data transmission energy consumption per GB from Sustainable Web Design. • AWS cloud lifecucle emissions obtained from Carbon footprint estimater for AWS instances. • BEIS 2022 Emission Factors. • 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. • Nuclear energy emission factor obtained from United Nations Economic Commission for Europe's report on Integrated Lifecycle Assessment of Electricity Sources.
Input adjustments and key considerations for usage of results	Variables to consider if using results in other use cases: • Total length of circuit lines • Average number of conductor sensors per km of line with DLR • Average number of weather stations per km of line with DLR • Types of lines, calculator only looks at 220kV and 400kV lines and the percentage split between these two types • Country selection – emission factors will need adjusting if location is not that of the pilot and default in the calculator to reflect the appropriate energy generation source mix • Line uprating characteristics – the average number of uprating per km of line and the avoided materials and fuel

	consumption required will vary due to the type of line and purpose for uprating • The market alternative for the lines that make up the reference scenarios and the percentage split between these
'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 dynamic line rating platform solution is scalable, while also having the potential to improve communities' quality of life through energy accessibility and emission reductions from grid decarbonisation.
Key areas for improvement	Within the scope of this case study, no verification of the data was undertaken, and the calculator assumes the data provided by Red Eléctrica de España and Telefónica is correct. Key areas for improvement include: 1. To improve the cloud energy consumption calculation, the energy consumption of the exact servers hosting the DLR Platform should be measured (currently using an estimate from secondary data for an EC2 workload). 2. The calculator should seek to include LCAs of the different solution components if they become available The calculator should be updated with any improvements in data quality around user-interface and platform emissions to include these emissions in the calculation and quantify them as accurately as possible. 3. The DLR installation emissions should be quantified to make the calculator more accurate, particularly when Reference Scenario II is relevant.

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