Appendix E – Energy & Power Sector Methodology

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EGDC ICT Methodology

EUROPEAN GREEN DIGITAL COALITION

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

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

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

Global Enabling Sustainability Initiative (Coordinator)

DIGITALEUROPE

European Telecommunications Network Operators' Association

European DIGITAL SME Alliance

SUB-CONTRACTORS

Carbon Trust

Deloitte

GSMA

Sustainable ICT Consulting

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

Introduction

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

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

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

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

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

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

- **Telefónica, Dynamic Line Rating** – The Dynamic Line Rating (DLR) is a cloud-based platform that allows transmission system operators (TSO) to operate circuits using real time data and forecasts. Better knowledge of the lines' real conditions enables the use of the idle capacity that is inaccessible when using seasonal ratings, optimising the power capacity of the existing electricity transmission grid. The increase in the capacity of the network allows for greater integration of renewable energy into the grid. The DLR solution can also avoid adverse environmental impacts such as the manufacturing of steel structures and the use of large cranes which are involved in uprating lines, which is the alternative to implementing DLR. GHG emissions are reduced due to the decreased need for manufacturing transmission line parts, and the integration of renewables into the grid.
- **IBM, Flex Platform** – The IBM Flex Platform is an intelligent grid optimisation solution which enables electricity consumers to connect their electrical assets (e.g. ventilation systems, comfort cooling, cold storage, heat pumps, EV charging stations) and offer their aggregate demand-side flexibility, helping balance the electricity grid at the transmission level and avoid bottlenecks at the distribution level. One of the impacts of demand-side flexibility enabled via the IBM Flex Platform is substituting the balancing capacity delivered by reserve power plants, thereby avoiding greenhouse gas emissions.

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

How to use this document

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

Methodology Application in the Power & Energy Sector

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

Defining the Assessment

Assessment Objective

The assessor shall define the following:

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

Telefónica, Dynamic Line Rating

The assessment intent is to determine to what extent the Dynamic Line Rating (DLR) solution can have a net positive carbon impact on the transport sector when implemented in a specific context. Furthermore, the aim of the assessment was also to test the EGDC's "Net Carbon Impact Assessment Methodology for ICT Solutions" and identify sector-specific methodological considerations.

IBM, Flex Platform

The assessment intent is to understand the net carbon impact of the implementation of the IBM Flex Platform solution in municipal buildings in Copenhagen.

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

Telefónica, Dynamic Line Rating

The assessment considers the implementation of the solution in multiple contexts, namely across two different types of transmission lines, 220kv and 400kV lines, in mainland Spain.

IBM, Flex Platform

The assessment will only consider one implementation context, which is ventilation assets in Copenhagen municipal buildings connected to the Flex Platform.

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

Telefónica, Dynamic Line Rating

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.

IBM, Flex Platform

The assessment is ex-post, using data collected during the implementation of the solution in 2023.

Solution Description & Boundary

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

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

Telefónica, Dynamic Line Rating

The Dynamic Line Rating (DLR) solution combines a dynamic line rating system and a cloud-based platform. It enables transmission system operators (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 solution optimises 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.

IBM, Flex Platform

The IBM Flex Platform is an intelligent grid optimisation solution which enables electricity consumers to connect their electrical assets (e.g. ventilation systems, comfort cooling, cold storage, heat pumps, EV charging stations) and offer their aggregate demand-side flexibility, helping balance the electricity grid at the transmission level and avoid bottlenecks at the distribution level. One of the impacts of demand-side flexibility enabled via the IBM Flex Platform is substituting the balancing capacity delivered by reserve power plants, which is the focus of this case study. Through this effect, the solution is expected to generate a positive impact in the power sector by reducing GHG emissions from reserve power plants.

The IBM Flex Platform is designed to accommodate the need from the three primary actors in the market for flexibility services; an electricity consumer providing demand-side flexibility (Flex Provider), the Aggregator (incl. Balancing Responsible Party) and the electricity system operator that is receiving the flexibility (i.e. the Transmission System Operator (TSO) for ancillary services).

The IBM Flex Platform has been designed and built to activate demand-side flexibility from electrical assets owned and managed by large commercial and public electricity consumers. The solution makes it possible for an electricity consumer (a Flex Provider) to make an agreement with an Aggregator (and their Balance Responsible Party when relevant) to control the demand-side flexible assets by temporarily reducing (or potentially increasing) the power consumption according to the balancing need in the power grid. This way, it reduces the need to use a regulating (often fossil fuelled) power plant to maintain the balance of power in the grid, thereby reducing GHG emissions.

The Flex Platform is based on a configuration of the Internet of Things (IoT) Service, a set of trained and exposed Flex Asset Models implemented as part of the AI Service and a configured Blockchain Service for keeping track of agreements, forecasted, reserved, and delivered flexibility.

The IoT Service is connecting the flexible assets to the Flex Platform by an integration layer, which is used for instrumenting and aggregating the flexible assets so they can be used as a flex portfolio.

The IoT Service does not connect directly to the individual building assets, but through an existing Building Management System (BMS).

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

Telefónica, Dynamic Line Rating

Optimising transmission circuit capacities: DLR can increase the capacity of the network to integrate renewable energy into the electricity transmission grid.

Optimising existing transmission system infrastructure: The DLR solution entails the installation of sensors along existing transmission lines instead of uprating the lines which involves building new lines. Installing the DLR solution can therefore avoid adverse environmental impacts such as the manufacturing of steel structures, the use of large cranes which are involved in uprating lines. This reduces GHG emissions due to the need for less manufacturing of transmission line parts.

IBM, Flex Platform

The IBM Flex Platform aggregates the capacity of electrical assets to balance the grid, substituting the balancing capacity traditionally provided by fossil fuelled reserve power plants, thereby reducing GHG emissions.

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

Telefónica, Dynamic Line Rating

The Dynamic Line Rating solution is expected to have an impact in the power sector.

IBM, Flex Platform

The Flex Platform is expected to have an impact in the power sector.

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

Telefónica, Dynamic Line Rating

The solution requires a connection to a telecommunications 4G/5G network and therefore is limited to locations where this infrastructure is available.

IBM, Flex Platform

The main technical limitation of the solution is that it requires an existing BMS to connect to.

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

Telefónica, Dynamic Line Rating

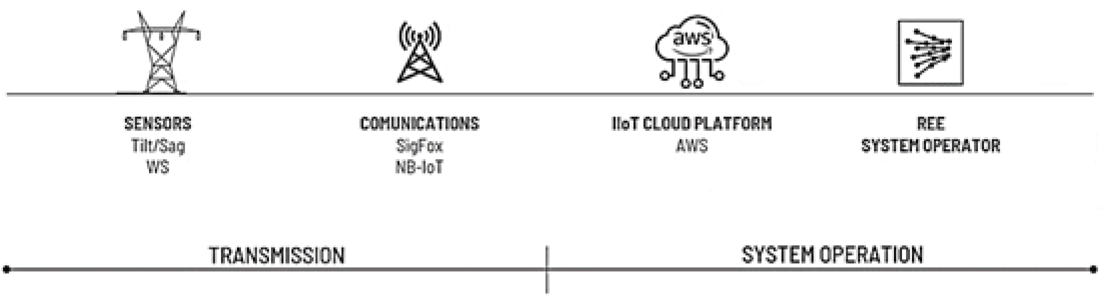
Digital components:

The ICT solution is made up of conductor sensors, provided by REE and local weather stations, from Telefónica, which include a data logger, and wind, temperature and solar sensors. The solution also requires cloud-based storage provided by AWS. The data transfer required for the solution is provided by Telefónica's 4G/5G network across Spain. Furthermore, the ICT solution requires local personal computers, for informing the transmission system operators of the solution.

Non-digital components:

The solution functionality depends on the transmission network infrastructure (lines, towers) which is provided by Red Eléctrica de España (REE).

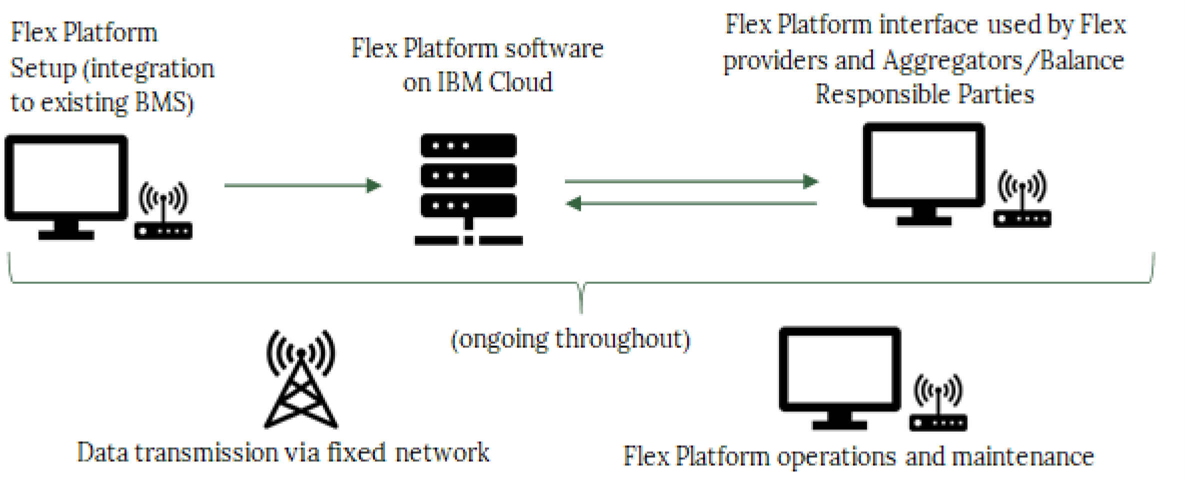
The DLR installation requires car travel by engineers, and the use of typical tools.



IBM, Flex Platform

The following components comprise the IBM Flex Platform:

- BMS system(s) for assets onboarded to Flex Platform
- Flex Platform software including user interface
- IBM Cloud to host software
- Desktop computer and router to access interface
- Data transmission network
- Electrical assets (ventilation systems)



Functional Unit

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

(i) Function relevant to both reference and enabled scenarios

(ii) Unit quantity

(iii) Performance

Telefónica, Dynamic Line Rating

The functional unit for the solution is **tonnes of CO2e per kilometre of transmission line in mainland Spain per year.**

The function is that the ICT solution is transmitting electricity to its users.

The unit quantity in this instance is the length, in kilometres, of transmission line.

The performance would be around the efficiency of energy generation and transmission of electricity within a year.

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 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 tonnes of CO2 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 solution scenario when assessed. The savings also change proportionally as the number of kms of line changes.

IBM, Flex Platform

The chosen functional unit is kWh delivered per year.

The function of the Flex Platform is to provide balancing capacity for the grid, which is achieved by aggregating capacity available in electrical assets connected to the platform and bidding into the balancing market. This function is fulfilled by reserve power plants in the reference scenario. The performance required is a balanced power grid throughout the year. The unit quantity is kWh delivered as that is the common unit between both the reference and solution scenarios.

Assessment Boundary

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

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

Telefónica, Dynamic Line Rating

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO2e. It has been assumed that 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.

IBM, Flex Platform

The emission factors used to calculate the net carbon impact of the ICT solution cover all GHG emissions covered by the Kyoto Protocol and are reported in terms of CO2e.

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

Telefónica, Dynamic Line Rating

The time boundary is the year 2022 for the ex-post assessment and the year 2026 for the ex-ante assessment of the renewable integration.

IBM, Flex Platform

The assessment estimates the net carbon impact for the 2023 calendar year.

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

Telefónica, Dynamic Line Rating

The geographical boundary for this assessment is mainland Spain.

IBM, Flex Platform

The geographical boundary for this assessment is Copenhagen, Denmark.

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

Telefónica, Dynamic Line Rating

The solution has been implemented in 13 circuits across mainland Spain, covering 533 kilometres of line. Two circuits have 400kV lines and the other eleven circuits consist of 200kV lines.

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The implementation context considers three-line transformation alternatives to DLR: no physical line alternative, a transition to uprating alternative, and a line uprating alternative. The lifetimes of each of the assets are outlined in the table below:

Asset	Lifetime (years)
Dynamic line rating	10
Line uprating	20
Line transition to uprating	23

The implementation context includes the Spanish electricity generation mix with DLR implemented, of which over 16% is from solar and wind sources, as well as the grid's annual electricity generation of 273,211 GWh.

IBM, Flex Platform

This assessment is for the deployment of the solution in municipal buildings in the city of Copenhagen, Denmark, specifically considering the impact of ventilation system assets that are connected to the IBM Flex Platform. Other types of electrical assets have different profiles for flexibility provision, therefore could result in different net carbon impacts.

Reference Scenario Definition

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

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

(ii) Be relevant to the given implementation context.

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

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

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

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

Telefónica, Dynamic Line Rating

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The reference scenario is the alternative transformation that existing lines in the pilot assessment would have undergone if the DLR solution would not have been implemented. The three transformation alternatives, and their percentage split, are known and were provided by Red Eléctrica de España (REE) who implements the solution across its transmissions system:

- No uprating alternative (54% of lines)
- Transition alternative which delays line uprating (38% of lines)
- Line uprating alternative (8% of lines)

The market average scenario was not researched in this assessment because the specific reference scenario was known.

IBM, Flex Platform

The reference scenario for this case study is what typically happens in the ancillary services market (specifically for manual reserves (mFRR) in the DK2 market) in Denmark when there is a balancing need in the power grid, without the implementation of the IBM Flex Platform. Energinet, the Danish Transmission System Operator, defines the demand and timing of flexible energy (ancillary) services needed to maintain the balance of power in the grid. Various approved parties then bid to supply ancillary services to meet demand in each specific hour. For the manual reserves market, Energinet only buys upward regulation reserves and sorts the bids according to the price per megawatt (MW), generally covering its need by selecting bids according to increasing price.

Bidders for ancillary services can supply energy from renewable or non-renewable sources. IBM has indicated that, in the reference scenario, the weighted average emission factor for reserve power plants delivering flexibility is 0.8 metric tons CO_2/MWh. This was agreed with Energinet.

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

Telefónica, Dynamic Line Rating

This requirement is not relevant for this assessment because the known reference scenario for the specific implementation context is used.

IBM, Flex Platform

This requirement is not relevant for this assessment because the known reference scenario for the specific implementation context is used.

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

Telefónica, Dynamic Line Rating

In the reference scenario, 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.

IBM, Flex Platform

This has been covered in (A) above.

Identifying Effects

Identifying Reference and ICT Solution Scenario Activities and Emission Sources

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

Telefónica, Dynamic Line Rating

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

Reference scenario	ICT solution scenario
Electricity generation	Electricity generation
Electricity transmission	Electricity transmission
Transmission line uprating /transition to uprating – manufacturing of infrastructure	Manufacturing of DLR components
Transmission line uprating /transition to uprating – installation of infrastructure	DLR installation

IBM, Flex Platform

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

Reference scenario	ICT solution scenario

Reserve power plant energy generation for grid balancing	IBM Flex Platform providing grid balancing
	IBM Flex Platform installation, operation and maintenance

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

Telefónica, Dynamic Line Rating

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources
Electricity generation	Electricity generation emissions from grid mix energy sources	Electricity generation	Electricity generation emissions from grid mix energy sources
Electricity transmission	Electricity transmission emissions	Electricity transmission	Electricity transmission emissions
Transmission line uprating /transition to uprating – manufacturing of infrastructure	Infrastructure (steel and concrete) embodied emissions	DLR component manufacture	Hardware embodied emissions (weather station sensors, conductor sensor)
Transmission line uprating /transition to uprating – installation of infrastructure	Truck fuel consumption Crane fuel consumption	DLR installation	Network lifecycle emissions (4G/5G) Personal computer in-use emissions

	Engineer vehicle fuel consumption Simple tool energy consumption emissions		Cloud processing and storage in-use emissions Platform and software in-use emissions Engineer vehicle fuel consumption Simple tool energy consumption emissions

IBM, Flex Platform

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources
Reserve power plant energy generation for grid balancing	GHG emissions from reserve power plants	IBM Flex Platform providing grid balancing	No GHG emissions (operational emissions captured below)
		IBM Flex Platform installation, operation and maintenance	Cloud processing and storage (data centre) in-use emissions Data transmission network in-use emissions (fixed) User/operations team Flex Platform access via PC (in-use) emissions

Identifying Potential Effects of Solution Implementation

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

Telefónica, Dynamic Line Rating

Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources	GHG emission impacts
Electricity generation	Electricity generation emissions from grid mix energy sources	Electricity generation	Electricity generation emissions from grid mix energy sources	Reduction in energy generation emissions from renewable integration due to increased renewable energy sources.
Electricity transmission	Electricity emissions	Electricity transmission	Electricity emissions	No change in electricity transmission emissions.
Transmission line uprating /transition to uprating – manufacturing of infrastructure	Infrastructure (steel and concrete) embodied emissions	DLR component manufacture	Hardware embodied emissions (weather station sensors, conductor sensor)	Increase in hardware emissions from weather stations and conductor sensors. Decrease in emissions

				from avoided concrete and steel uprating infrastructure manufacture.
Transmission line uprating /transition to uprating – installation of infrastructure	Truck fuel consumption Crane fuel consumption Engineer vehicle fuel consumption Simple tool use emissions	DLR installation	Network emissions (4G/5G) Laptop/mobile use emissions Cloud processing and storage emissions DLR platform software use-phase emissions Engineer vehicle fuel consumption Simple tool use emissions	Increase in emissions from network, laptop, data centre, and platform software. Decrease in avoided truck and crane fuel consumption. No change in simple use of tools and engineer vehicle fuel consumption.

IBM, Flex Platform

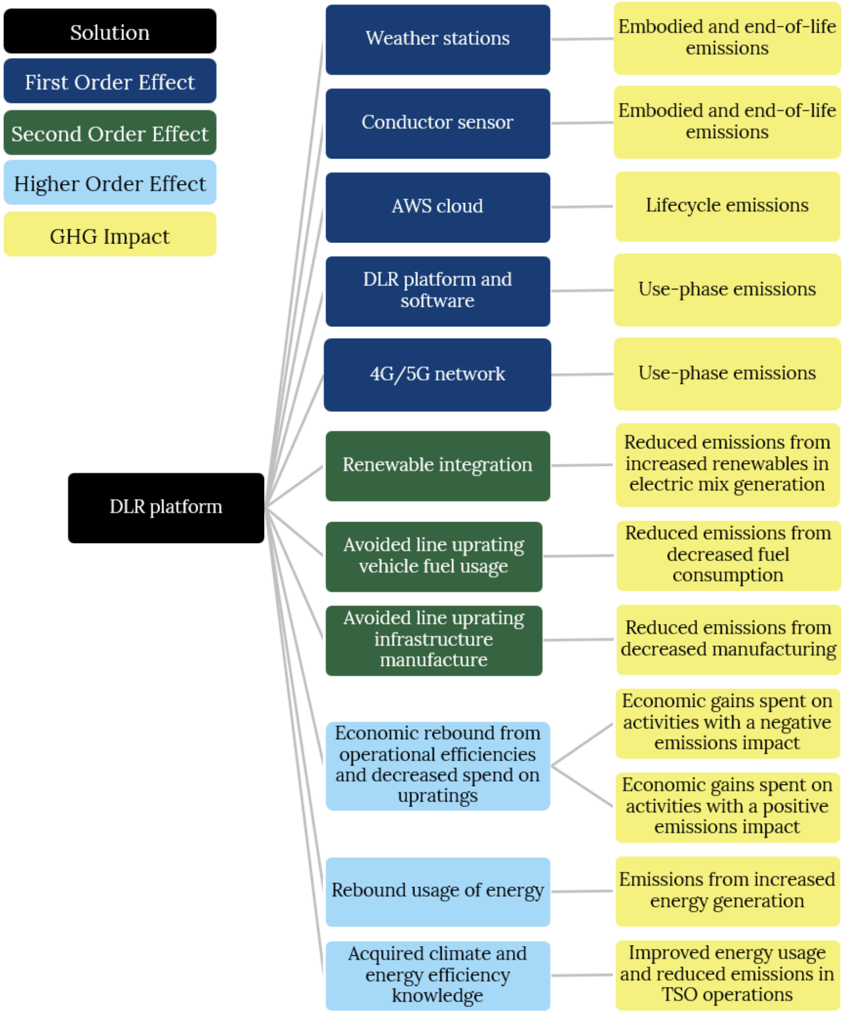
Reference scenario	Potential emission sources	ICT solution scenario	Potential emission sources	GHG emission impacts
Reserve power plant energy generation for grid balancing	GHG emissions from reserve power plants	IBM Flex Platform providing grid balancing	No emissions (operational emissions captured below)	Reduction in emissions related to

				grid balancing.
		IBM Flex Platform installation, operation and maintenance	Cloud processing and storage (data centre) emissions Data transmission network emissions (fixed) User/operations team Flex Platform access via PC emissions	Increase in emissions from use of IBM Flex Platform.

Mapping Effects in a Consequence Tree

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

Telefónica, Dynamic Line Rating



IBM, Flex Platform

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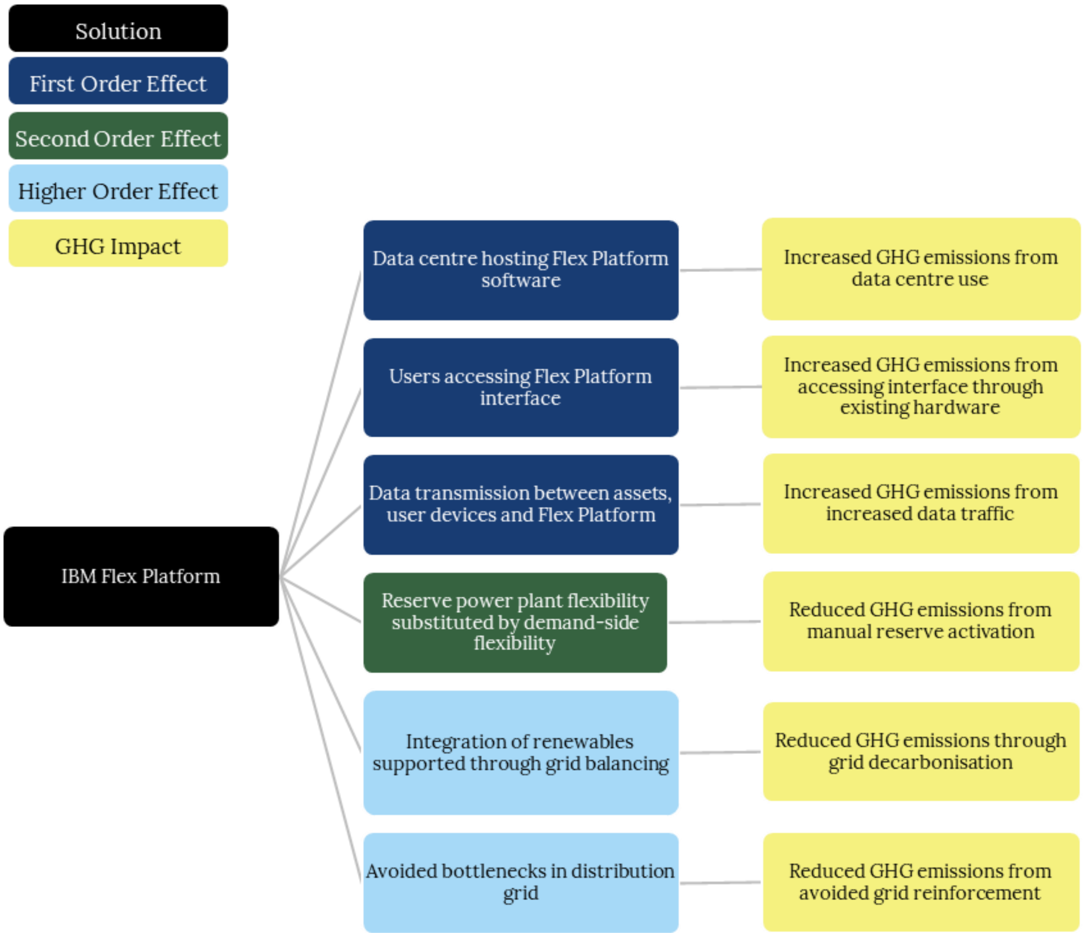

Identify First Order Effects

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

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

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

Telefónica, Dynamic Line Rating

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Based on the results from the previous steps of identifying effects, the following GHG emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Embodied (incl. transport), end-of-life and in-use emissions of hardware** (weather stations (wind sensor, temperature sensor, solar ration sensor, datalogger) and conductor sensor) – as this hardware was not required before the implementation of the solution and is not part of the reference scenario, both the embodied and in-use emissions and should be considered for the calculation of first order effects.
- **Telecommunications network emissions (4G/5G)**
  - The marginal increase in **in-use network emissions** is not part of the reference scenario and therefore should be considered for the calculation of first order effects.
  - The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Personal computer / software emissions**
  - New software associated with the ICT solution (DLR platform software) was not present in the reference scenario. The marginal increase in **in-use emissions from personal computers used to operate the solution** is not part of the reference scenario and therefore should be considered as first order effects.
  - It is assumed that the **embodied (incl. transport) and end-of-life emissions of the personal computers** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data centre processing and storage emissions**
  - The marginal increase in **in-use emissions from data centre processing and storage** are not part of the reference scenario and therefore should be considered as first order effects.
  - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

IBM, Flex Platform

Based on the results from the previous steps of identifying effects, the following GHG emissions were identified to not be part of the reference scenario and must therefore be considered as first order effects:

- **Data centre processing and storage emissions (IBM Cloud)**
    - The marginal increase in **in-use emissions from data centre processing and storage** are not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of datacentres used for processing and storage** are already in existence even without the implementation of the solution in place, as they are unlikely to be built solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Data transmission network emissions (fixed)**
    - The marginal increase in **in-use network emissions** is not part of the reference scenario and therefore should be considered for the calculation of first order effects.
    - The **embodied (incl. transport) and end-of life emissions of the network** are already in existence even without the implementation of the solution in place, as the network is unlikely to have been upgraded solely for this solution. These emissions are therefore excluded from the calculation of first order effects.
- **Personal computer and router emissions**
    - The software associated with the Flex Platform solution was not present in the reference scenario. The marginal increase in **in-use emissions from personal computers and routers used to operate the solution** is not part of the reference scenario and therefore should be considered as first order effects.
    - It is assumed that the **embodied (incl. transport) and end-of-life emissions of the personal computers and routers** are already in existence even without the implementation of the solution in place, as they are unlikely to be purchased solely for this solution. These emissions are therefore excluded from the calculation of first order effects.

Identify Second & Higher Order Effects

(A) All second order effects shall be identified.

(B) All higher order effects shall be identified.

Telefónica, Dynamic Line Rating

Based on the results from the previous steps of identifying effects, the following second and higher order effects were identified:

Second order effects:

- An increase in renewables in the electricity generation mix through reduced renewable spillage which improves the decarbonisation of the electric system.
- A decrease in the manufacturing of concrete foundations and steel infrastructure needed for uprating transmission lines.
- A decrease in the fuel consumption of trucks and cranes needed for uprating transmission lines.

Higher order effects:

- Renewable integration in the Spanish grid may result in an 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.
- Optimisation of existing transmission system infrastructure may result in economic savings due to direct cost savings from the avoided uprating installation and manufacturing costs. These economic savings may be used for carbon emitting or saving activities impact and result in an increase or decrease in GHG emissions.
- 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 transmissions system operators (TSOs) or of the whole electric system, reducing overall emissions.

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

IBM, Flex Platform

Based on the results from the previous steps of identifying effects, the following second and higher order effects were identified:

Second order effects:

- The IBM Flex Platform allows for electrical demand-side assets to react to the balancing needs demanded by the TSO, by reducing (or increasing) the power consumption of electrical assets to maintain the balance of power in the grid, similar to the way a regulating power plant is acting in the ancillary services market today. Therefore, the amount of flexibility delivered, in MW, by IBM Flex Platform assets substitutes flexibility otherwise delivered by reserve power plants. This results in carbon savings from avoiding the activation of reserve power plants.

Higher order effects:

- As fossil fuelled energy production continues to be replaced by renewables, production will fluctuate much more. As a result, the need for balancing resources will grow over the coming years. It is pivotal to engage with electricity consumers to help balance the grid if more renewables are to be phased into the energy system. Therefore, the IBM Flex Flatform can support the decarbonisation of the grid by enabling demand-side flexibility.
- Smart balancing solutions like the IBM Flex Platform can help avoid bottlenecks in the distribution grid and thereby can help avoid the resources (and associated GHG emissions) needed to reinforce the grid to avoid bottlenecks.

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

Calculating Effects

Estimating the Relative Magnitude of Effects

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

Telefónica, Dynamic Line Rating

Effect type	Effect	Description	Timespan	Relative magnitude
First order	Weather stations (temperature, wind, solar radiation sensors, and datalogger)	Hardware embodied and end-of-life GHG emissions footprint, relatively small due to magnitude of second order effects.	Short	Small/Medium
First order	Conductor sensor	Hardware embodied and end-of-life GHG emissions footprint,	Short	Medium

		relatively small due to magnitude of second order effects.		
First order	AWS cloud	Energy consumption related to data centre processing and storage emissions expected to be very small relative to other effects.	Short	Low
First order	DLR platform and software	Energy consumption related to accessing and running the solution platform and software via a PC.	Short	Low
First order	4G/5G telecommunicati ons network	Energy consumption related to data transmission across the telecommunications network.	Short	Low/Medium
Second order	Renewable integration	Transmitting a greater amount of renewable sourced energy through the Spanish grid.	Medium	High
Second order	Avoided line uprating vehicle fuel usage	Fuel consumption from cranes and trucks used for uprating transmission lines.	Short/ Medium	Medium/High
Second order	Avoided line uprating infrastructure manufacture	Manufacturing of cement and steel infrastructure for line uprating.	Short/ Medium	Medium/High
Higher order	Economic rebound	Economic rebound from operational efficiencies and decreased spend on upratings.	Medium/ Long	Medium
Higher order	Rebound energy usage	Increased use of energy by end users due to renewable	Medium/ Long	Medium

		integration enabled by the solution.		
Higher order	Acquired knowledge	Acquired knowledge of climate and energy efficiency can improve energy consumption in other areas of the TSO/users, reducing emissions.	Long	Low

IBM, Flex Platform

First order effects:

The Flex Platform software is hosted in an IBM data centre which results in a marginal increase in electricity consumption. Because the software uses AI models, there is a high possibility that the energy consumption is not insignificant, and it is very important to collect data on this effect.

Accessing the Flex Platform through the user interface via a PC (whether this is done by Flex asset providers, aggregators/balance responsible parties, or the operators & support team) is not expected to produce a large marginal increase in energy consumption relative to the data centre hosting. The same applies to the marginal increase in energy consumption by the router used with the PC. However, there should still be an effort to collect this data as end-user devices do consume energy that is not insignificant.

The data that is transmitted between the assets, user devices and Flex Platform results in increased electricity use in the data transmission network. Networks are generally energy efficient, with energy intensities expected to improve in the future. Historically, the electricity intensity of network data transmission has halved roughly every two years since 2000[1]. Therefore, for small amounts of data transmission, the impact of this effect is not expected to be significant.

Second order effects:

The emissions savings from displaced reserve power from fossil-fuelled power plants are expected to be one of the most material impacts amongst all effects. It is imperative to get accurate data for the power sources that are being displaced by the IBM Flex Platform in order to make the calculation credible.

Higher order effects:

[1] Carbon-impact-of-video-streaming.pdf

The IBM Flex Flatform can support the decarbonisation of the grid through more renewables integration by enabling demand-side flexibility. This systems-level impact involves many variables and there would have to be enough flexibility provided by the platform in order for this effect to materialize in the medium term. However, in terms of scale, it could be a very material positive impact.

Smart balancing solutions like the IBM Flex Platform can help avoid bottlenecks in the distribution grid and thereby can help avoid the resources (and associated emissions) needed to reinforce the grid to avoid bottlenecks. This would be a significant positive impact as grid reinforcements are emissions intensive.

Data Collection

Identifying Key Activities for each Effect

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

Telefónica, Dynamic Line Rating

Effect	Description	Activities

First order	Embodied (incl. transport), use-phase and end-of-life emissions of hardware
	• Weather stations
	  • Wind sensor
	  • Temperature sensor
	  • Solar radiation sensor
	  • Datalogger
	• Conductor sensor
		Number of devices per functional unit
		Cradle to grave footprint of hardware devices
		Material breakdown of hardware devices (type and weight of material)
		Likely disposal method of devices
		Energy usage per device over lifetime
		Power consumption of device and usage profile
		Electricity grid emission factor (GHG emissions per kWh)
		Material emissions factors incl. end-of-life (GHG emissions per unit)

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First order	In-use network emissions	Marginal electricity consumption of network due to DLR platform. Electricity grid emission factor (GHG emissions per kWh).
First order	In-use emissions from laptops used to operate the solution platform and software	Marginal electricity consumption of laptops due to operate the DLR platform and software. Electricity grid emission factor (GHG emissions per kWh).
First order	In-use emissions from AWS cloud data centre processing and storage	Marginal electricity consumption of data centres due to the DLR platform solution. Electricity grid emission factor (GHG emissions per kWh).
Second order	A reduction in fuel consumption due to avoided vehicle use for line upratings (trucks and cranes)	Fuel consumption by fuel type for lines that are uprated vs lines with DLR implemented. Fuel emission factor (GHG emissions per unit).
Second order	Transmitting a greater amount of renewable sourced energy through the Spanish grid.	Spanish total annual energy generation (kWh) with and without DLR. Spanish grid mix with and without DLR split by energy source. Emission factors for each electricity source.
Second order	Manufacturing of cement and steel infrastructure for line uprating.	Number of uprating materials per functional unit

		Material breakdown of infrastructure (type and weight of material) required for uprating a line. Likely disposal method of materials.
Higher order	Economic rebound from operational efficiencies and decreased spend on upratings.	Number of DLR implementations and upratings before and several years after implementation of the DLR solution. Total energy consumption of users before and several years after implementation of the DLR solution. Income and likely spending habits of uses (TSOs) before and several years after implementation of the DLR solution.
Higher order	Increased use of energy by end users due to renewable integration enabled by the solution.	Total energy consumption of users before and several years after implementation of the DLR solution.
Higher order	Acquired knowledge of climate and energy efficiency can improve energy consumption in other areas of the TSO/users, reducing emissions.	Total energy consumption of users before and several years after implementation of the DLR solution. Literature that looks into the conditions of power lines and the utilisation of their idle capacity over several years with and without the solution.

IBM, Flex Platform

Effect	**Description**	**Activities**
First Order	In-use data transmission network emissions	Marginal energy consumption of network due to solution Amount of data transfer over the network

		Network energy intensity (kWh energy use per GB data transfer) Electricity grid emission factor (GHG emissions per kWh)
First Order	In-use emissions from personal computers / software and routers used to operate the solution	Marginal energy consumption of personal computers and routers due to operation of solution Average computer power draw (W) User profiles (hours) Router energy intensity (kWh/GB) Annual data transmission rate (GB)
First Order	In-use emissions from data centre processing and storage	Marginal energy consumption of data centres due to solution Dedicated server energy consumption Data centre PUE Electricity grid emission factor (GHG emissions per kWh)
Second order	Avoided emissions from displaced kWh flexibility provided by reserve power plants	Amount of kWh flexibility provided by IBM Flex Platform GHG emission factor for reserve power plants that were displaced (based on historic data / counterfactual based on flexibility bidders that would have been awarded the contract if IBM Flex Platform was not in the market)
Higher order	Decarbonisation of the grid through more renewable integration by enabling demand-side flexibility	Increase in renewables in local grid (before vs after Flex Platform introduction) Data on factors affecting renewable integration

Higher order	Avoid the resources (and associated emissions) needed to reinforce the grid to avoid bottlenecks	Data on factors affecting grid reinforcement decisions. GHG emissions avoided from avoided grid reinforcements after introduction of Flex Platform

Data Quality and Availability Assessment

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

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

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

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

(iii) The relative magnitude of the effect.

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

Telefónica, Dynamic Line Rating

Effect	Activities	Data for activity available?	Data Quality
Embodied (incl. transport), use-phase and end-of-life emissions of hardware	• Number of devices per functional unit • Cradle to grave footprint of hardware devices • Material breakdown of hardware devices (type and weight of material)	• Yes • No • Yes • No • Yes • No • Yes	• Good • N/A • Fair – weight and materials used to estimate embodied emissions. • Poor - assumption

	• Likely disposal method of devices • Energy usage per device over lifetime • Power consumption of device and usage profile • Electricity grid emission factor (GHG emissions per kWh) • Material emissions factors incl. end-of-life (GHG emissions per unit)	• Yes	• N/A - Weather stations and conductor sensor are battery powered or solar powered so have no energy consumption emissions • N/A • Good- Lifecycle Spanish electricity grid emission factor available from secondary source • Fair - Material emission factors available from secondary sources
In-use network emissions	• Marginal energy consumption of network due to DLR platform • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Very good (LCA on network available) • Good- Lifecycle Spanish electricity grid emission factor available from secondary source
In-use emissions from laptops used to operate the solution platform and software	• Marginal energy consumption of laptops due to operate the DLR platform and software • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Poor – information from secondary sources used as proxy • Good- Lifecycle Spanish electricity grid emission factor available from secondary source

In-use emissions from AWS cloud data centre processing and storage	• Marginal energy consumption of data centres due to the DLR platform solution • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Fair – information from secondary sources, specific to AWS cloud, used as proxy • Good- Lifecycle Spanish electricity grid emission factor available from secondary source
A reduction in fuel consumption due to avoided vehicle use for line upratings (trucks and cranes)	• Fuel consumption by fuel type for lines that are uprated vs lines with DLR implemented • Fuel emission factor (GHG emissions per unit)	• Yes • Yes	• Fair - truck and crane hours of use per uprating provided (before vs after DLR implementation), secondary sources required for the litres per hour for each vehicle type • Good – diesel emission factor from reliable source (BEIS, 2022)
Transmitting a greater amount of renewable sourced energy through the Spanish grid.	• Spanish total annual energy generation (kWh) with and without DLR • Spanish grid mix with and without DLR split by energy source. • Emission factors for each electricity source.	• Yes – actual and projected data provided for the year, modelled with Plexos software • Yes - actual and projected data provided for the year, modelled	• Good – a year's worth of data on actual and projected energy generation • Good – a year's worth of data on actual and projected Spanish grid mix

		with Plexos software • Yes	• Fair - electricity sources' emission factors available from secondary sources
Manufacturing of cement and steel infrastructure for line uprating.	• Number of uprating materials per functional unit • Material breakdown of infrastructure (type and weight of material) required for uprating a line	• Yes • Yes	• Very good – actual data on quantities of materials per uprating, and upratings per km of line • Very good - actual data on materials (type and weight) per uprating
Economic rebound from operational efficiencies and decreased spend on upratings.	• Number of DLR implementations and upratings before and several years after implementation of the DLR solution • Total energy consumption before and several years after implementation of the DLR solution • Revenue and likely spending habits of uses (TSOs) before and several years after implementation of the DLR solution	• No, data not available for several years after implementation of DLR platform • No, data not available for several years after implementation of DLR platform • No data/information on spending habits available and information would be difficult to get	• Not applicable
Increased use of energy by end users due	• Total energy consumption of end-users before and several	• No, data not available for several years after	• Not applicable

to renewable integration enabled by the solution.	years after implementation of the DLR solution	implementation of DLR platform	
Acquired knowledge of climate and energy efficiency can improve energy consumption in other areas of the TSO/users, reducing emissions.	• Total energy consumption of users before and several years after implementation of the DLR solution • Literature that investigates the conditions of power lines and the utilisation of their idle capacity over several years with and without the solution	• No, data not available for several years after implementation of DLR platform • No, data not available for several years after implementation of DLR platform	• Not applicable

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

- Economic rebound from operational efficiencies and decreased spend on upratings.
- Induction from increased use of energy by end users due to renewable integration enabled by the solution.
- Acquired knowledge of climate and energy efficiency can improve energy consumption in other areas of the TSO/users, reducing emissions.

IBM, Flex Platform

Effect	Activities	Data for activity available?	Data Quality
In-use data transmission network emissions	• Marginal energy consumption of network due to solution • Amount of data transfer over the network	• No • Yes	• N/A • Good – primary data sample

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	• Network energy intensity (kWh energy use per GB data transfer) • Electricity grid emission factor (GHG emissions per kWh)	• Yes • Yes	• Fair – public proxy, Western EU average • Good
In-use emissions from personal computers / software and routers used to operate the solution	• Marginal energy consumption of personal computers and routers due to operation of solution • Average computer power draw (W) • User profiles (hours) • Router energy intensity (kWh/GB) • Annual data transmission rate (GB)	• No • Yes • Yes • Yes • Yes	• N/A • Fair – public proxy • Fair – IBM estimate • Fair – UK proxy • Good – primary data sample
In-use emissions from data centre processing and storage	• Marginal energy consumption of data centres due to solution • Dedicated server energy consumption • Data centre PUE • Electricity grid emission factor (GHG emissions per kWh)	• No • Yes • Yes • Yes	• N/A • Good/fair – average server sample • Very good • Good

Funded by the European Union

Avoided emissions from displaced kWh flexibility provided by reserve power plants	• Amount of kWh flexibility provided by IBM Flex Platform • Emission factor for reserve power plants that were displaced (based on historic data / counterfactual based on flexibility bidders that would have been awarded the contract if IBM Flex Platform was not in the market)	• Yes • Yes	• Good – primary data • Fair/poor – figure agreed with the Transmission System Operator (TSO), but no evidence presented
Decarbonisation of the grid through more renewables integration by enabling demand-side flexibility	• Increase in renewables in local grid (before vs after Flex Platform introduction) • Data on factors affecting renewable integration	• No • No	• N/A • N/A
Avoided resources (and associated emissions) needed to reinforce the grid to avoid bottlenecks	• Data on factors affecting grid reinforcement decisions • Emissions avoided from avoided grid reinforcements after introduction of Flex Platform	• No • No	• N/A • N/A

First Order Effects

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

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

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

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

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

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

Telefónica, Dynamic Line Rating

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 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 Report2 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.

[2] Life Cycle Assessment of Connectivity Solutions - Telefónica (telefonica.com)

Please refer to the sections on assumptions and key areas for improvement for the relevant caveats and limitations of the first order effect calculations.

IBM, Flex Platform

The first order effects calculation includes the estimated emissions from the data centre, data transmission network and user device energy consumption associated with the Flex Platform's use for the city of Copenhagen.

The Flex Platform software is hosted on IBM Cloud, specifically on 6 servers in 3 data centres in Germany (for Copenhagen deployment). The watt usage of relevant racks in the data centres was measured across a 4-week period to get an average watt usage estimate for each server (dividing the 4-week average watt usage per rack by number of devices per rack). For each of the 6 servers relevant to Copenhagen's use of the Flex Platform, the watt usage per server was multiplied by the data centre specific PUE and scaled up to get an annual kWh energy use estimate (i.e. multiplied by 8760 to reflect operation 24 hours a day/365 days a year). Based on this estimate of server energy use, energy use of storage and networking in the data centres are estimated based on an assumed distribution of power usage by hardware subsystem, supported by academic literature – see Figure 1.8 in *The Datacenter as a Computer by Barroso, Luis André, et al*[3]. The total of server, storage and networking energy use make up the total energy use of the data centre related to the Flex Platform. The data centres run on renewable energy, therefore there are zero emissions associated with this layer of the solution.

The data transmission network energy use is estimated by multiplying an average Western Europe fixed network energy intensity figure (0.0065 kWh/GB) by an estimate of the annual data transmission related to the solution for the Copenhagen deployment (4,250 GB). The network intensity figure, taken directly from a recent report on the *Carbon impact of video streaming*[4], is for the year 2020 therefore should provide a conservative estimate given expected annual improvements in network energy intensity. The emission factor applied to the network energy use estimate is an average of the lifecycle electricity grid factors for Germany and Denmark (2022) from the Association of Issuing Bodies.

The user device energy use is estimated in two parts. First, desktop computer energy use is estimated by multiplying an estimated typical user profile (hours/year) for Flex providers, Aggregators/Balance Responsible Parties, and Operators & support team by the assumed power draw of a typical desktop computer (115 W).

Second, router energy use for all the above users is estimated by multiplying the annual data transmission (4,250 GB) by an estimate of router energy intensity (0.025 kWh/GB, taken from the

[3] The Datacenter as a Computer by Barroso, Luis André, et al

[4] Carbon impact of video streaming

report *Carbon impact of video streaming*). Due to lack of data on enterprise router energy intensity, the router energy intensity used is for a 10 W home router.

The emission factor applied to the total user device energy use is the lifecycle electricity grid factor for Denmark (2022) from the Association of Issuing Bodies.

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

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

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

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

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

Telefónica, Dynamic Line Rating

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 installation of the DLR solution 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.

IBM, Flex Platform

No identified first order effects were excluded from the calculation.

Second Order Effects

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

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

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

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

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

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

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

Telefónica, Dynamic Line Rating

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 grid due to renewable integration.

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.

IBM, Flex Platform

The 2nd order effects calculation captures the GHG savings from substituting flexibility provided by reserve power plants with the demand-side flexibility enabled by the Flex Platform.

A sample of hourly data from the Copenhagen deployment (37 unique ventilation assets, 70 day time series) was provided including the forecast and delivered flexibility per asset per hour. The forecast is an estimate of the flexibility that an asset could provide during a given hour (and is reserved), whilst the delivered flexibility is what was actually purchased in the market and delivered.

Figures for three variables were derived from the data sample: the average kW flexibility reserved per asset per hour, the average number of hours per day that flexibility is reserved per asset, and the percentage of reserved flexibility that is delivered. These variables are used to develop a profile of an archetypal day in the year for ventilation assets in Copenhagen providing demand-side flexibility (in kWh). The flexibility delivered in an archetypal day is multiplied by 365 days in a year and the resulting annual flexibility delivered is multiplied by the emission factor for reserve power plants delivering flexibility in the reference scenario (0.8 tCO_2e/MWh) to capture the avoided emissions.

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

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

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

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

Telefónica, Dynamic Line Rating

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

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IBM, Flex Platform

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

Higher Order Effects

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

Telefónica, Dynamic Line Rating

Qualitative assessment of identified higher order effects:

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Economic rebound	Economic rebound from operational efficiencies within the transmission lines as they are utilised at a greater capacity, and decreased spend on the infrastructure required for upratings as they are avoided with the implementation of the DLR solution.	Medium/ Long	Medium	Medium	Medium
Rebound energy use	A potential increase in the use of energy by end users due to the perceived use of energy with low emissions from renewable integration enabled by the solution.	Medium/ Long	Medium	Low/ Medium	Weak

Acquired climate and energy efficiency knowledge	Acquired knowledge of climate and fuel efficiency can improve energy consumption in other areas of the TSO/users, reducing emissions.	Long	Low	Low	Weak

IBM, Flex Platform

Qualitative assessment of identified higher order effects:

Higher order effects	How and where they would occur	Timeframe	Expected magnitude	Likelihood of effect occurring	Causal relationship to solution?
Integration of renewables supported through demand-side grid balancing, resulting in reduced grid emissions intensity	Demand-side grid balancing will be needed if more renewables are to be phased into the energy system. This higher order effect would occur in the local grid where demand-side grid balancing through the Flex Platform is active.	Medium-long term	Medium	Medium	There are many factors that determine how many renewable assets are built and integrated into the grid. It is recognised that demand-side grid balancing will be needed to continue to integrate renewables into the grid, so there is a causal relationship, but it is indirect because there are many

					concurrent influencing factors that contribute to that outcome.
Avoided bottlenecks in distribution grid, resulting in avoided emissions from reduced need for grid reinforcement	Smart balancing solutions like the IBM Flex Platform can help avoid bottlenecks in the distribution grid and therefore reduce the need for grid reinforcement. This higher order effect would occur in the local grid where demand-side grid balancing through the Flex Platform is active.	Medium-long term	Medium	Medium	Grid reinforcement is planned well in advance, so the solution would need to be sufficiently scaled up in order to have the beneficial impact. There is an indirect causal relationship.

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

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

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

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

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

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

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

Telefónica, Dynamic Line Rating

Economic rebound: This higher order effect was excluded due to insufficient data on the economic savings arising from the implementation of the solution. Efforts should be made to collect data on the economic savings from the operational efficiencies, specifically any savings from the increased utilisation of the transmission lines' power capacity that would have been idle without the solution's implementation. Similarly, there is no data/information on the cost savings associated with the avoided line upratings, and spending habits of the TSOs. In the future, cost savings from the avoided upratings, such as the costs related to the manufacture and installation of the infrastructure, and how these savings are spent, should be collected. However, information on spending habits is expected to be difficult to obtain.

Rebound energy use: This higher order effect was excluded as an increase in energy consumption has a weak causal link to the implementation of DLR.

Acquired climate and energy efficiency knowledge: This potential higher order effect was excluded as it is expected to have a low likelihood of occurrence and lacks evidence of a causal relationship with the solution.

IBM, Flex Platform

As the time frame for the identified higher order effects is medium-long term and the extent of the causal relationship between the solution and the effect needs further investigation, the data is not available to assess them quantitatively. However, excluding these positive effects makes the net carbon impact calculation more conservative.

Net Carbon Impact Calculation

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

Telefónica, Dynamic Line Rating

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

IBM, Flex Platform

Total carbon saving impact: 3.4 tCO2e / year

1st order effects: 0.1 tCO2e/year

2nd order effects: 3.5 tCO2e/year

Savings from reference scenario (%): Not applicable

Saving per functional unit: 0.001 tCO2e / kWh delivered / year

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

Telefónica, Dynamic Line Rating

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

IBM, Flex Platform

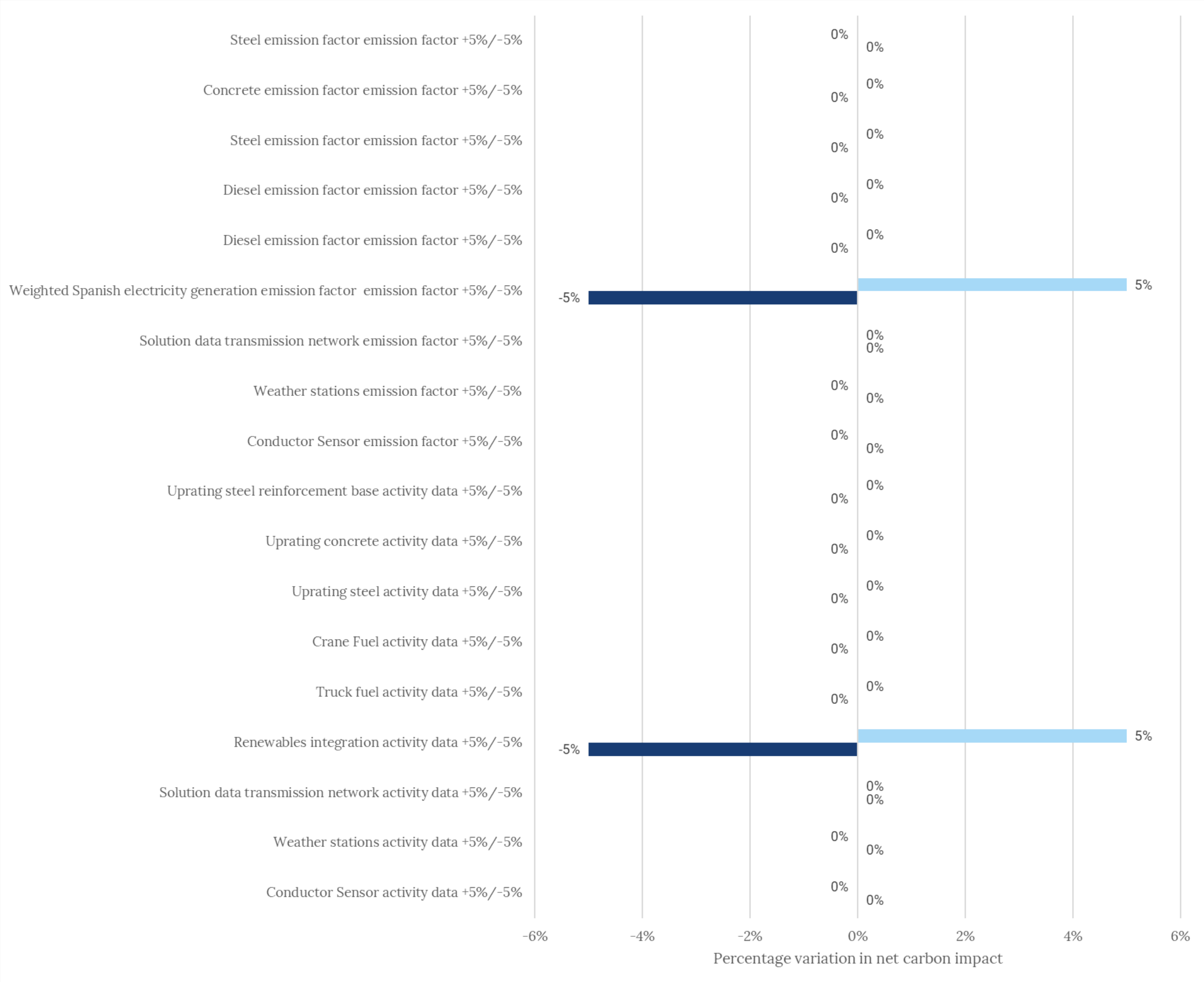
Any changes during the time period of the assessment, such as changes in emission factors, have been considered in the calculation.

Uncertainty and sensitivity analysis

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

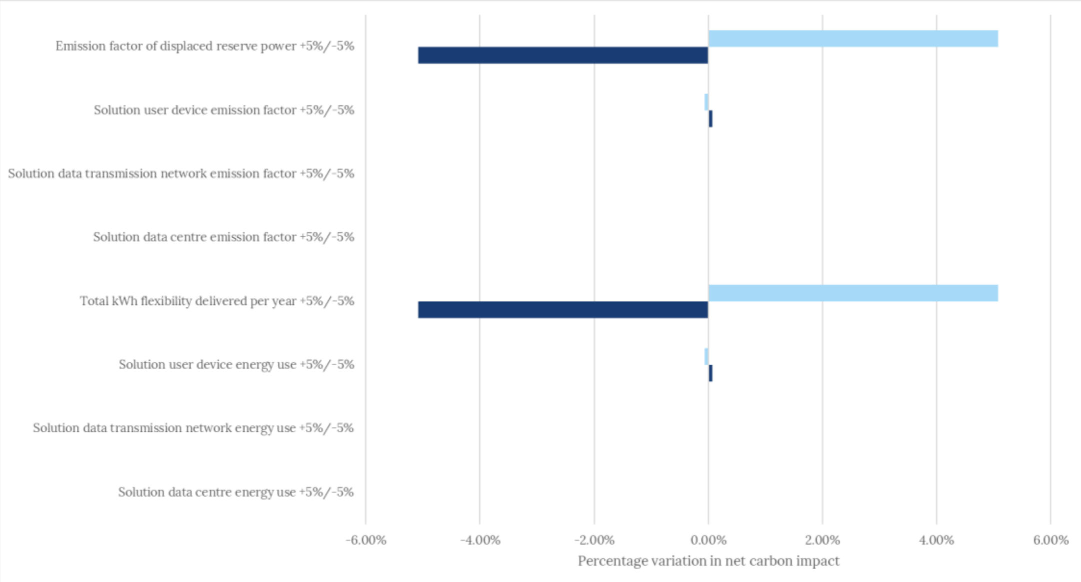
Telefónica, Dynamic Line Rating

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 47,589tCO2e. Alternatively when the activity data is varied by +5%, the net carbon impact increases to 52,598tCO2e. 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 tCO2e has a sensitivity of +/- 2,505 tCO2e, when assessing implementation contexts of varying renewables integration.



IBM, Flex Platform

The sensitivity analysis indicated that the net carbon impact results are most sensitive to the data related to the second order effect of displacing flexibility typically provided by reserve power plants. This applies to both the emission factor for power from reserve power plants and the activity data about how much flexibility is delivered by the Flex Platform to displace that reserve power. Varying these inputs by +5% and -5% results in a change in the net carbon impact of +5.08% and -5.08%, respectively.



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

Telefónica, Dynamic Line Rating

The qualitative uncertainty analysis assesses the quality of the data inputs. It demonstrates that 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 is specific to the activity, by collecting primary data on the truck and crane fuel consumption.

			Qualitative Assessment of Data Quality				
Data type	Impact effect	Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity Data	1st order	Conductor Sensor	Very good	Very good	Very good	Very good	Very good
	1st order	Weather stations	Good	Very good	Very good	Good	Good
	1st order	Solution data transmission networ	Very good	Very good	Very good	Very good	Very good
	2nd order	Renewables integration	Very good	Very good	Very good	Good	Very good
	2nd order	Truck fuel	Poor	Good	Fair	Fair	Fair
	2nd order	Crane Fuel	Poor	Good	Fair	Fair	Fair
	2nd order	Uprating steel	Very good	Very good	Very good	Very good	Very good
	2nd order	Uprating concrete	Very good	Very good	Very good	Very good	Very good
	2nd order	Uprating steel reinforcement base	Very good	Very good	Very good	Very good	Very good
Emission factors	1st order	Conductor Sensor	Good	Fair	Fair	Fair	Fair
	1st order	Weather stations	Good	Fair	Fair	Fair	Fair
	1st order	Solution data transmission networ	Very good	Very good	Very good	Very good	Very good
	2nd order	Weighted Spanish electricity gener	Fair	Good	Good	Fair	Fair
	2nd order	Diesel emission factor (truck)	Good	Very good	Good	Very good	Good
	2nd order	Diesel emission factor (crane)	Good	Very good	Good	Very good	Good
	2nd order	Steel emission factor	Good	Fair	Fair	Fair	Fair
	2nd order	Concrete emission factor	Good	Fair	Fair	Fair	Fair
	2nd order	Steel emission factor	Good	Fair	Fair	Fair	Fair

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

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from the Greenhouse Gas Protocol on Quantitative Inventory Uncertainty:
https://ghgprotocol.org/sites/default/files/2022-12/Quantitative%20Uncertainty%20Guidance.pdf

IBM, Flex Platform

The uncertainty analysis, which qualitatively assesses the quality of the data inputs, highlighted that the data quality of the emission factor for power from reserve power plants was only 'fair' or 'poor' among the criteria of time, reliability and completeness. This should be a focus for improvement because it is a key determinant of the net carbon impact result.

The other data inputs that had the greatest weaknesses against the quality criteria were the activity data related to the data transmission network and user devices; these were scored as 'fair' for the time, geography, reliability and completeness criteria.

Data type	Impact effect	Description of effect	Activity	Time	Geography	Reliability	Completeness
Activity Data	1st order	Solution data centre energy use	Very Good	Fair	Very Good	Very Good	Fair
	1st order	Solution data transmission network energy use	Very Good	Fair	Fair	Fair	Fair
	1st order	Solution user device energy use	Good	Fair	Fair	Fair	Fair
	2nd order	Total kWh flexibility delivered per year	Very Good	Fair	Very Good	Very Good	Good
Emission factors	1st order	Solution data centre emission factor	Very Good	Very Good	Very Good	Good	Very Good
	1st order	Solution data transmission network emission factor	Very Good	Good	Good	Good	Poor
	1st order	Solution user device emission factor	Very Good	Good	Very Good	Good	Very Good
	2nd order	Emission factor of displaced reserve power	Very Good	Fair	Very Good	Fair	Poor

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

Recalculation

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

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

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

Telefónica, Dynamic Line Rating

As the solution's carbon impact is highly dependent on the Spanish grid mix and the split between the reference scenarios, the assessment will need to be reviewed annually to determine whether the average reference scenario needs to be updated, as this could change the results by more than 5%.

IBM, Flex Platform

The assessment should be reviewed annually given the needed improvements in data quality and the sensitivity of the results to the emission factor of displaced reserve power.

Other considerations for a net carbon impact assessment

Do No Significant Harm

Telefónica, Dynamic Line Rating

The solution is not expected to cause significant harm in other ESG areas. In the long term, as the dynamic line rating platform solution is scalable, it has the potential to improve communities' quality of life through energy accessibility and emission reductions from grid decarbonisation.

IBM, Flex Platform

There are no foreseen negative impacts on any of the EU Taxonomy's environmental nor social objectives, and the solution strongly supports objective 1: Climate change mitigation.

Using Results in Other Implementation Contexts

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

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

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

Telefónica, Dynamic Line Rating

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

- Types of lines – The assessment only considers 220kV and 400kV lines and the percentage split between these two types of lines. If the solution is applied on a different type of line with significant differences in characteristics compared to the lines in the assessment, such as its power carrying capacity, this will impact the second order effect of the solution. The first order effects such as the average number of conductor sensors and weather stations per km of line may need to be adjusted. The number of upratings per km of line, and the infrastructure and installation resources required to uprate the new type of line may also need to be adjusted to accurately depict a new implementation context.
- Location/Geography – Emission factors will need adjusting if the location changes and the default in the calculator will need to be updated to reflect the appropriate energy generation source mix.
- Line uprating characteristics – The average number of upratings per km of line and the avoided materials and fuel consumption required will vary due to the type of line and purpose for transforming the line.
- Line transformation alternative – The alternative for the lines that make up the reference scenarios and the percentage split between these may also need to be updated.
- Different weather station or conductor sensor suppliers - If the suppliers of the hardware differ in the new implementation context, this could be updated and adjusted in the assessment. However, given the immateriality of these emissions to the overall net carbon impact, if data is not available or the new suppliers are unknown, the assessment could be used within this context without the need for adjustments.
- Energy generation source mix – the decarbonisation of the grid over time, driven by increased investment and energy generation coming from renewable sources, will be reflected in the reference scenario energy grid mix. As the Spanish grid mix shifts away from fossil-based energy sources, the net carbon impact of the solution will likely decrease.
- Types of lines – Two types of lines, 220kV and 400kV lines, are considered in the assessment. Different types of lines will have different characteristics and power carrying capacities which will directly impact the electricity transmission within the circuit. Additionally, the number of upratings per km of line as well as the number of solution components per km of line could impact the first order and second order effect.
- Fuel type of vehicles -the truck and crane used in the uprating reference scenario are diesel vehicles. Due to increased incentives to reduced GHG emissions (i.e. policies), it is possible that alternative fuels that are less carbon intensive may be used to replace the

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diesel used in these vehicles. It is likely that in the future, the vehicle and machinery will be electrified or replaced by zero emission vehicles.

- The DLR market alternative – The alternative(s) to the DLR solution (i.e. no physical alternative, a transitory transformation or line uprating) make up the reference scenario and have a great impact on the carbon impact of the solution as the carbon saving mechanisms may differ between them. Alternative line transformations besides those outlined in the assessment may arise due to new innovations. The different types of transformations and the proportion of each scenario making up the average reference scenario will impact the potential carbon savings.

IBM, Flex Platform

- The emission factor of displaced reserve power is entirely location dependent, therefore any changes to the location of solution implementation must re-evaluate the reference scenario and supporting data.
- Reference scenario emissions (reserve power plants) – the reference scenario for this solution is highly location specific and must be adjusted for each different implementation context. The emissions intensity of reserve power plants in the assessment is very high – less emissions-intensive reserve power for grid balancing would reduce the positive second order effect.
- Amount and type of electrical assets providing flexibility – the calculator specifically considers the impact of ventilation system assets. The type of asset affects its flexibility profile (how much flexibility it can offer throughout the day), and the number of assets affects the scale of the flexibility that can be aggregated and reserved to be bid into the market. Changing the combination of these two factors could increase or decrease the second order effect.
- Solution energy use and emissions – the solution energy use should be reassessed if there are any changes to the implementation context. The solution data centre energy use is the largest component of the total solution energy use; however, it results in zero emissions in the current context due to the data centre running on renewable energy. If this were to change, the first order effect would be much larger.
- The current calculator only considers ventilation assets in the context of office buildings – other types of assets, in other contexts, will have different flexibility profiles i.e. offer different quantities of kW flexibility at different hours.
- All other implementation parameters should also be adjusted for new implementation contexts, including both activity and emission factor data. The results are highly sensitive to chosen inputs - if the platform data centre was not running on renewable electricity, this would add a large negative emissions impact to the calculation, resulting in an overall negative net GHG impact for this deployment, if all other variables remain constant.

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Communicating and Documenting Outcomes of a Net Carbon Impact Assessment

Communicating and documenting outcomes of a single ICT solution

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

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

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

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

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

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

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

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

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

Telefónica, Dynamic Line Rating

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

IBM, Flex Platform

The above requirements have been disclosed in the Case Study Methodology document for the IBM Flex Platform, which can be found here.

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