EGDC Case study: c-BEMS

April 2024

Case Study Methodology

Provided by: Inteligg

EUROPEAN GREEN
DIGITAL COALITION

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

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

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

Global Enabling Sustainability Initiative (Coordinator)

DIGITALEUROPE

European Telecommunications Network Operators' Association

European DIGITAL SME Alliance

SUB-CONTRACTORS

Carbon Trust

Deloitte

GSMA

Sustainable ICT Consulting

1 Introduction

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

The main aim of the EGDC is to maximise the sustainability benefits of digitalisation within the ICT sector, while supporting sustainability goals of other key sectors such as energy, transport, agriculture, and construction. The Coalition recognises the need for science–based methods to estimate the reduction and avoidance of greenhouse gas (GHG) emissions by specific ICT solutions across sectors. This will accelerate the sustainability and circular transitions of these sectors while contributing to an innovative, inclusive, and resilient society.

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

This case study methodology accompanies the c-BEMS case study calculator and provides further details, additional context and transparency around the case study calculator to ensure the outcomes of the case study are interpreted and used correctly.

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

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

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

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

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

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

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

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

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2 Methodology

c-BEMS	
Assessment Objective	The assessment is intended to determine to what extent the Inteligg solution can have a net positive impact on the building sector. Furthermore, the aim of the assessment was also to test the EGDC ICT Sector Guidance for Net Carbon Impact Assessments and identify sector-specific methodological considerations. The assessment is ex-post and considers the implementation of the solution in multiple contexts, namely in an office building (Belgium) and two residential apartments (Greece).
Solution Description	Inteligg P.C. is a European company focussing on developing building energy management systems (BEMS). c-BEMS is its cloud-based BEMS, enabling multi-zonal control of heating, cooling (HVAC) and lighting systems, which reduces a building's energy consumption. Inteligg's Software as a Service (SaaS) model employs various Internet of Things (IoT) devices in different rooms to measure the temperature, humidity, and occupancy rates of these spaces. Using Artificial Intelligence (AI) and Machine Learning (ML), c-BEMS calculates energy consumption behaviour, thermal modelling of the building, and energy demand. This enables its Model Predictive Control which stabilises indoor temperature, lowers it when the room is unoccupied and therefore optimises energy usage. This way, c-BEMS reduces overall energy demand, therefore reducing GHG emissions in the buildings sector. The solution has also been used and proved in an academic paper written by Bagheri *et al.*, entitled "Use of

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	AI Algorithms in Different Building Typologies for Energy Efficiency towards Smart Buildings”. A minimum requirement is a stable Wi-Fi connection that provides a wireless network with the corresponding amount of data collected by the right numbers of sensors according the energy system and building type (or even better according the m2 of surface applied area), something already expressed by the above mentioned academic paper. There are no known restrictions to the type of building the solution can be used in. The solution is currently deployed in multiple European countries, including Belgium, Greece, and Luxembourg. It has been used in residential buildings, offices, industrial, restaurants, and public buildings (including a church and town hall). All equipment, i.e., the smart thermostats, smart sensors and smart controllers are either provided by DVC-co and are manufactured for INTELIGG only under an agreement or are provided by Honeywell. WiFi connectivity is provided by local broadband network providers. Cloud computing is performed on Amazon Web Services.
Solution Boundary	• A smart sensor module including three sensors (or parameters) for measuring temperature (°C), relative humidity (%), and movement detection (binary signal); • A smart thermostat module including the sensors of a sensor module along with an LCD screen and 4 buttons allowing for manual settings (if necessary); • A smart control module featuring a number relays to control the operation of the HVAC systems. • Cloud computing is provided by Amazon Web Services • c-BEMS makes use of the home’s WiFi network • c-BEMS uses previously-installed heating systems, including boilers and radiators.

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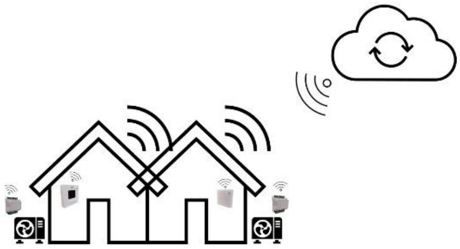

Functional Unit	The function is heating a building. The unit quantity is a singular building. The performance is heating a building efficiently to a comfortable indoor temperature. The chosen functional unit is kWh per degree day per year. The choice for kWh reflects the way energy is generally presented on energy bills and allows for a comparison across geographies and building types. Degree days are used to account for different climates and weather conditions. Whilst it is part of the functional unit, it is not provided as an output in the calculator. It is embedded in the back-end calculations of the model. The unit of years is chosen to control for the yearly cyclical nature of energy consumption, allowing for a comparison of measurements taken in different seasons and with different outside temperatures. A limitation of the functional unit is that the energy consumption (in kWh) is expected to decrease in the implementation scenario. The alternative of using kWh per square metre (or cubic metres) was not possible due to a lack of data on area size, building type and levels of insulation/ventilation.
Assessment Boundary	The calculation includes three buildings in Greece and Belgium. The first two are a residential apartment and a house in Greece and the second is an office building in Belgium. All three run on natural gas. The time boundary for the assessment is a single year.

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	No additional information on the buildings is known. This includes data on how old the buildings are, and what type of insulation and/or ventilation systems they have deployed.
Reference scenario	In the reference scenario, the buildings were heated using weekly programmed but manually adjustable thermostats without data-driven functionality or complex control strategies. It did not use technologies such as artificial intelligence or any modelling. This is considered the market average for building heating systems.
Description of 1st order effects	The following first order effects were identified: - Hardware lifecycle emissions (including transportation and end-of-life) of the thermostat, sensor and controller. There was no data on the hardware's expected lifetime so a conservative approach was taken to include the full life-time emissions. - Electricity consumption (in-use) lifecycle emissions from the thermostat, sensor and controller. There was no data on their power consumption so estimate was made using the energy consumption of a smart Google Nest module for all three devices (1 kWh per month each). The relatively power intensive Google Nest module was chosen taking a conservative approach. As a comparison, a similar Amazon smart thermostat uses less energy. - The Wi-Fi connectivity can be justified to have existed prior to the solution, so the lifecycle emissions related to the Wi-Fi's hardware are not included. However, the emissions related to the increased Wi-Fi usage resulting from the solution should be included. There was also no data the use of Wi-Fi and the resulting emissions. Again, a conservative approach was taken to take the peak measurements from an IoT device connected to Wi-Fi as researched by Yuksel, 2020. This equalled 3V and 247mA (0.741 kWh). It was assumed to remain at this peak for 24 hours a day, 365 days a year. - The data centres can be justified to have existed prior to the solution, so their lifecycle emissions have not been included. However, their use-phase emissions should be included. There was also no data on emission resulting from cloud

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	computing. Therefore, this calculation has been quantitatively excluded as it does not meet the 5% materiality threshold. See the calculator for this calculation. - The solution is not expected to require use of a laptop. If this changes, the use-phase emissions of the laptop should be included into the calculation as well.
Categorisation of digital technologies A=ICT Service B=Service specific building block C=Common ICT devices, services, infrastructure	**Digital components:** **B** The solution requires three devices to be installed in the apartment/house (Bagheri *et al.*, 2021): - A smart sensor module including three sensors for measuring temperature (°C), relative humidity (%), and movement detection (binary signal); - A smart thermostat module including the sensors of a sensor module along with an LCD screen and 4 buttons allowing for manual settings (if necessary); - A smart control module featuring a number relays to control the operation of the HVAC systems. Inteligg has partnered with DVC-co to provide these. **C** - Cloud computing is provided by Amazon Web Services - c-BEMS makes use of the home's WiFi network **Non-digital components:** - c-BEMS uses previously installed heating systems, including boilers and radiators.
Description of 2nd order effects	Inteligg's c-BEMS uses Artificial Intelligence to estimate when to turn on and off the heating. It does this by measuring data on occupancy levels, humidity, and a building's heat profile. By predicting and optimising energy demand in specific spaces, the solution reduces the overall amount of time the house is heated, cutting energy use and therefore GHG emissions. Data was collected from an office building and two apartments/houses. For both buildings, the yearly energy consumption was measured before the solution and a year after. This was from December 2021 to December 2022. This timeframe was chosen to control for the seasonal variance in energy demand. The indoor

	temperature was measured in the first month of the solution, and a year after the solution to ensure the reduction in energy usage did not offset a comfortable indoor temperature. The nearest weather stations were located to retrieve information on the outside temperature, measured in heating degree days. Degree days are a unit of measurement used to estimate the theoretical energy requirements that are expected for a location for each day in the year to keep a comfortable inside temperature. Widely used for energy monitoring, the degree days method assumes a building needs heating when the outside temperature is 15.5ºC or lower. This is lower than typical indoor temperatures, accounting for the generally warmer indoor environment caused by the occupants' body-heat and absorption of solar radiation. Every degree Celsius lower per day counts for one degree day. For instance, if the average outside temperature on a given day is 10ºC, 5.5 degree days are counted for that day. The data used for the reference scenario, provided by degreedays.net, is more granular and measures in timeframes shorter than an hour.
Description of higher order effects	There is some literature demonstrating a rebound effect when energy efficiency improvements are made, including for energy management systems that incentivise the user turning on the heating more often (e.g., Belaïd, Bakaloglou & Roubaud, 2018; Belaïd, Youssef & Lazaric, 2020). An economic rebound effect may result from saved costs on heating which can be used for carbon intensive or carbon saving activities and products. Improved knowledge on the building's energy consumption, and sustainability in general may help users make environmentally beneficial decisions. These higher order effects are excluded as there is a high uncertainty around their impact, there is a relatively weak claim to causality, and there is very little data availability.
Mapping of all effects	

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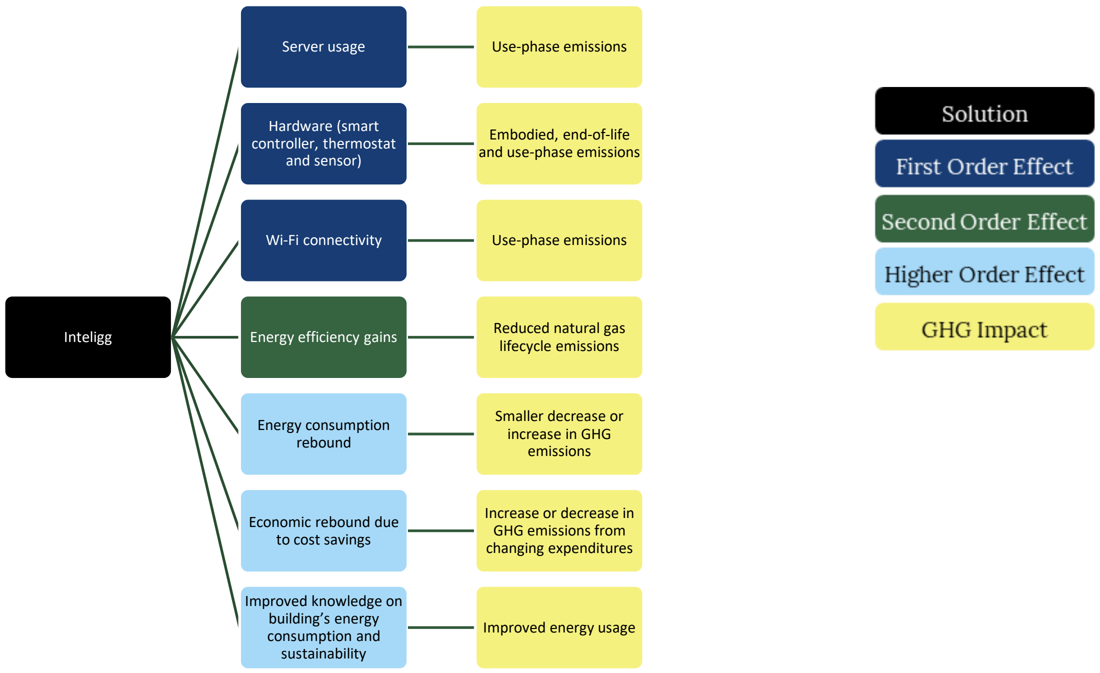

Description of calculation	**1st order effects:** The weight and material of each component was noted and multiplied by the respective GHG material and end-of-life conversion factors to calculate the associated emissions. As a conservative approach, the entire lifetime emissions of the devices are included. Their use-phase emissions were estimated using the energy consumption of a Google Nest module running 24 hours a day, 365 days a year, multiplied by the country's lifecycle electricity grid emission factors to obtain GHG emissions. The manufacturing and transportation emissions of the devices (smart controller module, smart thermostat and smart sensor module) were excluded due to lack of data availability. Assuming these usually contribute around 5% to the total lifecycle carbon footprint of the devices, this would equate to less than 1% of the total net carbon impact and can therefore be excluded. It is assumed that whilst every building needs one smart thermostat module and one smart controller module, an additional smart sensor module is required for every 50 square metres (rounded to the closest 50, so that 124 m^2 requires one smart sensor module, but 125 m^2 requires two).

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The emissions related to the use of Wi-Fi connectivity were estimated using Yuksel, 2020's research. It was assumed to run 24 hours a day, 365 days a year. The power consumption was multiplied with the electricity grid emissions factor to obtain GHG emissions.

2nd order effects:

Using data from Eurostat, the average household natural gas energy consumption that goes to space-heating was tabled for each European country. This percentage is multiplied with the input energy consumption for apartments. For offices, the assumption is made that 90% of energy use from natural gas goes towards heating. For apartments, it is assumed to be 60%.

By combining the yearly reduction in energy usage with that year's amount of local degree days (baselined at 15.5ºC), a calculation could be made of the average reduction in kWh per degree day (DD). Two different kWh/DD reduction factors were noted for apartment and office building types.

For each European country, monthly degree days were tabled for the years 2019, 2020, and 2021. The 2022 values (which were not yet released at the time of writing) were estimated using the three-year averages of each month in 2019-2021.

The average energy consumption per degree day (kWh / DD) before the solution was measured by dividing the inputted energy consumption by the amount of national degree days in that month or year (depending on whether monthly or yearly energy metre readings are provided).

To calculate the reduction in energy usage, the energy consumption per degree day is multiplied by the reduction factor appropriate for the building type.

The yearly expected energy consumption after the solution is calculated by multiplying the new energy consumption per degree day with the 5-year average yearly degree days for that location, divided by the previously used assumption of energy use from natural gas that goes towards heating (60% for apartments, 90% for offices).

If a monthly metre reading is given, an additional calculation is provided to estimate the energy usage that could have been saved were the solution in place for that

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	particular month. That is done by multiplying the reduced kWh / DD with the yearly degree days for that location and that year, and with the percentage that month was responsible for the overall degree days that year. The difference between the (expected) yearly energy usage before and after the solution is multiplied with the conversion factors for natural gas to calculate the carbon savings enabled.
Net Carbon Saving Impact of the Solution	**Apartments, Greece** 1st order effect: 16 kgCO2e/year 2nd order effect: 771 kgCO2e/year Total carbon saving impact: 755 kg CO2e / year Savings from reference scenario (%): 36% energy Saving per functional unit: 0.5 kWh / DD / year **Office, Belgium** 1st order effect: 6 kg CO2e/ year 2nd order effect: 53 kgCO2e/year Total carbon saving impact: 47 kg CO2e / year Savings from reference scenario (%): 3% energy Saving per functional unit: 0.02 kWh / DD / year
Qualitative data uncertainty and sensitivity analysis	The uncertainty analysis illustrates the particularly poor quality of the 2nd order effect data, which has a significant impact on the reliability of the results of the calculator. There is also considerable uncertainty around the activity data of the modules' energy consumption and Wi-Fi connectivity. The sensitivity analysis demonstrates that the outcome of the calculations show a low sensitivity to the 1st order effects (<1%). The second order effect has a higher sensitivity (~5%). To improve the reliability of the calculator, 2nd order effect data needs to become more reliable. 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

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Assumptions	It is assumed that - Year-over-year temperatures stay (relatively) constant; - The reference building is heated using natural gas; - The reference building is heated when the outside temperature drops below 15.5ºC; - For residential buildings, 60% of energy from natural goes to space heating, whilst for offices, 90% of energy goes to heating. - Every treated building requires one thermostat module and one controller. Inteligg estimates that one additional sensor module is required for each nearest 50m^2 .
Data sources	Data on energy consumption before and after the solution was provided by Inteligg. Moreover, the material and weight of each of the hardware components was provided by Inteligg. Inteligg also provided the nearest weather stations to the reference buildings. Degreedays.net was consulted to find the associated yearly degree days for these weather stations. The monthly degree days data for each European country was retrieved from Eurostat. Emission factors for the hardware lifecycle emissions and production and consumption of natural gas was taken from the UK government. The calorific value is not expected to differ significantly between European countries. Emission factors for the full lifecycle emissions of the electricity grid were taken from Carbon Footprint Ltd. The power consumption of the modules was estimated using Google's Nest module. The power consumption of the solution's part of the Wi-Fi network was estimated using Yuksel, 2020. The emission factor for Amazon Web Service's cloud hosting was taken from Climatiq.

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Input adjustments and key considerations for usage of results	Inputs:
	- Country building is located in
	- Building type
	  ○ Apartment
	  ○ Office
	- Current natural gas energy usage (kWh)
	  ○ Yearly
	  ○ Monthly
	- When the metre reading was taken
	  ○ Year of reading
	  ○ Year and month of reading
	It is to be considered that the solution is built on the presumption that the building is heated with natural gas. It also does not take into account climatic differences between regions within a single country. Instead, data on the national level is used.

'Do no harm' criteria	The solution is not expected to cause significant harm in other ESG areas.
Key areas for improvement	Data provided for this solution was severely limited. Within the scope of this work, there was no verification of the data undertaken and the calculator is based on the assumption the data provided by the solution is correct. Future calculators for building energy management systems may consider the following improvements. 1. Due to limited data, most carbon reductions calculated are around 3% for offices and 36% for apartments. Future calculators should include more data points with higher granularity to make these numbers more reliable. This would also allow for a more thorough analysis of other factors that might influence the solution's effectiveness, including for instance country, the type of ventilation system used, and area size. 2. This solution only manages a building's heating requirements. Publicly available sources such as Eurostat would allow a future calculation to also include cooling requirements. 3. A future calculator should consider more building types, and have more datapoints on each. 4. The limited data for this solution does not allow for an analysis of when the AI has optimised

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	heating requirements, i.e. whether this has already happened within the trial period or whether the point of optimisation is still to reach. 5. Given this solution is AI-run, for future calculators it would be valuable to have data on the first order emissions related to server usage. The solution could not provide us this data so estimates were used. 6. This calculator builds off the assumption that there are no smart metres or sensors in place before the solution is implemented. 7. The data considered for this solution only includes heating systems based on gas and radiators, considerably limiting its use (though this has been expanded since the beginning of this project and includes different energy sources). Future calculators should include alternative heating systems, including electric heating and heat-pump systems. This is even more pertinent considering the heating without fossil fuels will gradually become the norm in Europe. 8. Future calculators should consider the differences in climate within (rather than between) countries. For example, the north of France has a different climate to the south of France and a future calculator could take this into account. 9. As some measurements were taken during the COVID-19 pandemic, data may be less reliably extrapolated. 10. Future calculators should update publicly available climate data to factor in rising temperatures.