Using Analytics Software to Calculate End User Computing Device Energy Consumption and Scope 2 GHG Emissions

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Abstract

Following ratification of United Nations (UN) Framework Convention on Climate Change (UN, 1992), the Kyoto Protocol (UN, 1998) and the Paris Agreement (UN, 2015), the United Kingdom (UK) Government has committed to reduce greenhouse gas emissions (GHG) by 80% by the year 2050. The commitment is made in an attempt to slow climate change (HM Gov, 2011); a phenomenon scientifically proven to be driven by anthropogenic interference such as fossil fuel combustion (IPCC, 2018). Electricity supply is the highest contributor to UK GHG emissions at 32%, followed by Transport at 23% and Business at 17% (HM Gov, 2016). UK business emissions are high due to the fact that UK commercial organisations consume 43% of all UK energy (National Statistics, 2018). Almost half of this energy powers office heating and lighting with information and communication technology (ICT) being the next largest electricity consumer at 7% (ONS, 2017). This equates to 4.2 million tonnes of carbon dioxide equivalent (mtCO_2e) GHG annual emissions (HM Gov, 2016) and is the equivalent to over 895,000 cars driving on UK roads for one year (EPA, 2019).

As such, business ICT is identified by leading agents (GeSI, 2015) as a sector that can assist with GHG abatement via improved energy efficiencies and innovation. To understand the full impact of ICT GHG emissions both the data centre and end user devices need to be measured. A wide-ranging body of research highlighted in the literature review indicates the focus of ICT energy consumption analysis has shifted away from end user computer (EUC) systems during the 1980s and 1990s, towards focusing on large scale data centres operated by enterprise scale businesses and internet service providers. Currently, ICT data centre energy consumption and carbon emissions can be calculated using metrics such as Power Usage Effectiveness (PUE) (Green Grid, 2007) and Carbon Usage Effectiveness (CUE) (Green Grid, 2010).

This data is beginning to appear in very limited numbers of Company Annual Reports as part of the mandatory Scope 2 emissions reporting introduced in 2013 (HM Gov, 2013) and Corporate Social Responsibility (CSR) documents (see Literature Review). In contrast, similar EUC measurements do not appear as an identified source of electricity consumption and therefore emissions. This is because the metrics are not easily nor accurately identifiable as, unlike a data centre that is a static entity, the devices are often used in a myriad of locations. Instead, the emissions contribution of EUC is cloaked within Scope 2 (indirect, purchased electricity for own use) as part of general commercial operations (GHGP, 2019). Of the 32.4m people employed in the combined UK private (27m) and public (5.36m) sectors (House of Commons Library, 2018 and ONS, 2018), 64% use an EUC device as part of their job role (ONS b, 2017). Not specifically identifying the electrical consumption, and therefore GHG emissions, of 20.7m commercial computer users is arguably a major misrepresentation of energy consumption and emissions in the UK.

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Not understanding the data or magnitude of values attributed to this group also acts as a barrier of how to identify strategies to abate EUC related emissions, including electrical efficiency, productivity and ICT commuting. The objective of the overarching research is to create an application capable of accurately measuring and reporting EUC CO_2e emissions at scale to overcome such issues and barriers. Experiment 1 represents an initial step towards achieving this objective. Conducted in a commercial environment of over one thousand users, the experiment is designed to test the viability of enhancing an existing commercial grade, analytics software package capable of capturing EUC energy and usage data with a view to calculating valid EUC CO_2e measurements.

Keywords: Green IT; IT Sustainability; Carbon Footprint, GHG Emissions

Introduction

In order to calculate an accurate CO_2e emission value for any computer, two key metrics must be captured and noted. Firstly, the electricity consumption of the EUC device in kilowatt-hours (kWh) and secondly, the UK Government's annually published conversion rate for electricity to CO_2e (HM Gov, 2018). The latter conversion rate is deduced each year by the government based on the average fuel mix of electricity in the national grid and is based on internationally recognised methods (HM Gov, 2018). For 2018, this figure is 0.28307, having reduced by 15% from 2017 as more renewable energy has entered the grid. When multiplied by the kWh measurement, the result reveals the CO_2e emissions for the electricity consumed including carbon dioxide (CO_2), Methane (CH4), and Nitrous Oxide (N_2O) gasses. Obtaining the measurement of electricity consumed by EUC devices is less simple, even though software, tools, information and hardware capable of calculating energy consumption for EUC devices do exist (see Literature Review). As the accompanying literature review indicates, measurements can be captured by two methods. Firstly, on a per device basis and secondly, as an entire EUC group using real time analytics (Lakeside, 2019). Per device information can be calculated for personal computers, laptops and tablets using software such as Microsoft's now defunct Joulemeter (Microsoft, 2010), estimation sites, nameplate ratings or by connecting a wattmeter to the plug socket. Each of these approaches comes with limitations that render the processes unscalable and therefore inappropriate for commercial use.

The key limitations are as follows. Joulemeter software is no longer supported for latest operating systems having been taken back in house by Microsoft to concentrate on data centre metrics. Whilst similar software exists it requires each EUC device to be measured individually causing a labour overhead when scaled above twenty or more devices. Power estimation websites are equally labour intensive and open to inaccurate results. They rely on numerous (often over twenty) manual data entries coupled with an estimation of 'on time' hours to arrive at an estimated sum total of energy consumption. Hardware solutions, such as connecting a wattmeter between the device and power source, do offer accurate kWh energy consumption readings but suffer data collation issues as the process is manual and labour intensive plus mobile devices cannot be tracked when removed from offices. Finally, nameplate ratings are simply an indication of the expected power required which is useful when designing buildings and power requirements, but not suitable for energy consumption reporting as a kWh reading is not feasible.

These limitations indicate that to automatically capture EUC energy consumption and usage data at scale, a commercial grade analytics solution is required. Used primarily as a workspace analytics tool, Lakeside Systrack software offers such a capability. Leveraging a distributed database architecture that is stored on the endpoint, the software captures thousands of end-user data points per second, and compiles the results in a Microsoft SQL database. Amongst the hundreds of metrics available, three key measurements deemed vital to this experiment were identified. These include Power (W) per device, Electricity Consumption (kWh) per device, and On Time Observed (%). Capturing this information and

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triangulating it with the government CO_2e conversion rate for electricity consumed enables the objective of Experiment 1 to be achieved.

Methodology

The methodology follows a simple process of:

- Identifying an appropriate test environment
- Interview a key stakeholder to capture relevant information that may influence the experiment
- Using Lakeside Systrack to capture EUC power and energy consumption data for thirty days
- Analysing the data and calculating the CO2e units
- Discussing the results, limitations and recommendations
- Drawing conclusion

Identifying The Test Environment

In 2013 the UK Government introduced mandatory emissions reporting for all UK incorporated companies listed on the London Stock Exchange (LSE), a European Economic Area market, and New York Stock Exchange or NASDAQ, plus unquoted large companies incorporated in the UK, and large Limited Liability Partnerships (HM Gov, 2013). Measured in CO2e units and categorised as Scope 1 (Direct, company vehicles and fuel combustion), Scope 2 (Indirect, purchased electricity for own use) and Scope 3 (Indirect, supply chain) emissions, the results are published in annual Company and Director Reports (HM Gov, 2013).

The rationale behind the legislation addressing this group of organisations is that they are, in most cases, classified a 'Large Organisations' with over two hundred and fifty full time staff. This classification cumulatively represents 61% of the total UK workforce (House of Commons, 2018) and therefore identifies a group with such scale that it is capable of delivering significant emissions abatement if specifically legislated against. Based upon this classification, it was decided that a test environment must consist of at very least over two hundred and fifty users to capture data resembling the user personas, device variations and resulting EUC emissions of a (large) company subject to mandatory emissions reporting. Therefore, the results would support further research whereby results and findings would be shared with LSE listed, large companies and government entities to gauge likely levels of adoption or support for EUC emissions measurement.

Initially four prospective organisations were identified including Warwick University, a financial services organisation, a government transport agency and finally a county council. All four were of the correct size and known through association. Following talks with the university and the financial service company, both declined for different reasons. The university had concerns that despite the guarantee of anonymity of data it was felt that they could not sanction the process due to data privacy concerns. The financial services company were able to overcome the concerns raised by the university, although they felt the introduction of new software into a data centre introduced unnecessary risk.

The transport organisation conversely overcame both the prior concerns as they were a current Lakeside user and had experienced data obfuscation and that the software caused no network or performance issues. In this instance the agency finally declined to participate one week before testing was due to begin, stating that other projects had taken priority and resources were no longer available. Finally, Flintshire County Council agreed to the experiment as they too were a current Lakeside user and would be examining sustainable ICT practices in 2019. They felt that participating in the research would benefit their Sustainable Development and Environmental Management strategies. As such, the subject organisation selected was a UK government council supporting 1,126 computer users.

Interview

It was determined that certain external factors may affect or influence the energy measurement results. These included number of systems and type of EUC device, ratio of mobile workers, electricity

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supplier and price, plus mandated working hours. As such an interview was conducted with the key ICT stakeholder ahead of the data collection as follows.

What is the total number of computer systems supported by the council and what is the blend of EUC device type? The response confirmed that there were 1,126 EUC systems comprising of 18 desktops and 1,108 laptops mainly manufactured by Lenovo. It was noted that one laptop was currently not in use. This data was used to identify if any systems had been missed during the data capture process.

How many mobile workers do you have? Of the total users, 926 had mobile capability and 200 were static office only based workers. Whilst not used in this experiment, the information allowed discussion related to the source of mobile worker electricity and other related emissions such as the possible impact of ICT commuting emissions based on job role or personas.

What are the Council's standard working hours? The council opens between 8am and 5pm, Monday through to Friday. As such the working day consists of 9 hours and therefore the thirty-day test period consists of a theoretical maximum of 198 working hours. This result is reached by excluding the eight weekends experienced during the period. The rationale behind identifying work hours it to triangulate and ratify the 'on time' measurement as discussed below.

What is the name of your energy supplier and what is the price per kWh charged? The council were unable to confirm this and therefore an industry average tariff of 14.4p per kWh was applied. In this example the daily standing charge was not included as this additional cost is attributed to the entire council estate and without knowing the percentage of power consumed by the total ICT environment, a proportional cost could not be applied. As the objective of the experiment was to test the ability to capture energy related data and convert it to CO_2e the results were not affected by the lack of response.

Data Capture

The council represented a convenient test environment as it is a current Lakeside Systrack customer. This removed barrier and objection, plus accelerated the time to results as no period was required for installation of the software within the ICT environment. In order to capture sufficient data capable of delivering meaningful results a thirty-day test period was decided upon. This offers a one month, 24 hours by 7 days per week view of power and energy consumption values for the individual devices and their sum. Limitations were noted that January can be a 'slow' month with many workers taking extra holiday in the first week which would perhaps distort extrapolations to annual values. However, as the objective is to test the feasibility of capturing power and energy consumption this factor was deemed acceptable. Using a distributed database architecture, with agents installed on each physical device, the software captured measurements every fifteen seconds.

To obtain measurements, power and energy consumption is queried from the hardware bios counters in order to deliver an average power rating in Watts (W) and a total energy consumption figure in kilowatt-hours (kwh) for the test period. The agent gathers this data and sends a summary of endpoint data to the Systrack master server. This occurs regardless of location each time the EUC device connects to the internet or local area network (LAN). This aspect of the software enables a complete power and energy measurement and removes any concern that electricity consumed outside of the office environment may not be tracked.

Systrack is capable of collecting over 10,000 data points to report many themes such as end user experience management, asset optimisation and service desk augmentation. However, for the purposes of this experiment only data relevant to power, energy, associated costs, and on time were collected and analysed. The latter measurement was included for two reasons. Firstly, if an EUC device returns a higher power reading (W) yet a lower energy consumption (kWh) when compared to another device, then the on-time measurement will help to explain the outcome.

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As an example, a device operating for only 50% of the time can return a higher power (W) measurement than a device operating for 100% of the time, yet it will proportionately return a lower energy consumption (kWh) due to the fact it has only been switched on for half as many hours. Secondly, the metric would offer an understanding of the average work hours when staff were actively using the EUC devices. If the measure was too low then it would perhaps indicate an issue with the capture method. Equally if it was too high then it would suggest that staff are leaving devices logged on and powered overnight which may cause excessive energy consumption. During the data capture period it was noted that the software supports Microsoft Windows, Linux and Apple Mac OS operating systems. This excludes the measurement of Android (including Google Chrome) and Apple iOS mobile operating systems.

Whilst perhaps a restriction for subsequent research it proved inconsequential to this experiment as all devices ran supported operating systems. The captured data was extracted after the test period from the Systrack Master Server into a Microsoft SQL database format via an IT administrator computer. The data was then translated to a simple Microsoft .xls (Excel) spreadsheet with the initial columns, 'Power Watts (W)', Energy Consumed (kWh), Electricity Cost (£), and 'On Time Observed (%)' as indicated in Table 1 below. Please note that the full EUC name is obscured to ensure anonymity, and the table only represents the first few rows of the data captured.

Table 1 - Systrack Data Capture in Initial Format

Computer Name	Power Average (W)	Elec Monthly (kWh)	Elec Cost Monthly	On Time Observed (%)
PC30581.	88	63	6.29	97.4
PC30536.	101	60	5.93	80.4
PC30388.	88	53	5.29	82.3
PC21914.	101	44	4.41	59.8
PC30580.	89	33	3.25	50.2
LT22515.	40	29	2.84	97.6
LT22283.	41	27	2.67	87.2
LT22470.	45	26	2.55	77.7

Data Analysis

The data captured process returned results from 17 PCs, and 1,052 laptops. This indicated that 1 PC and 56 laptops had not responded during the test period. Upon examination, this was caused by incorrect configuration on the relevant EUC devices and therefore the total number accurately measured was reduced to 1,069. This amount met the original environment criteria and was deemed to be sufficient to represent a large company. Whilst the power and electricity monthly figures were judged to be valid when triangulated with the on-time observation (see results) the electricity cost was found to be different from 11.71 pence per kWh determined as the current non domestic average tariff reported by the UK Government (HM Gov, 2019).

Contact with Lakeside Software confirmed that the original standard value (9.98p) is a worldwide energy industry average and not an observed or localised value. Therefore, the data for the Elec Cost Monthly was removed and replaced with the equation (kWh x 11.71p)/100 to deliver a location-based energy cost value in £GBP. As the objective of the experiment was to measure and report CO_2e units, a fifth column was added with the heading, 'EUC Emissions Monthly (kgCO_2e)'. The column was then populated by using the government CO_2e conversion rate multiplied by the energy consumed (as

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previously described). The final data table used for the experiment results discussion is as shown in Table 2.

Table 2 - Lakeside Systrack Data Capture in Enhanced Format

Computer Name	Power Average (W)	Electricity Consumption Monthly (kWh)	Electricity Cost Monthly (£)	On Time Observed (%)	EUC Emissions Monthly (kgCO2e)
PC30581.	88	63	£7.38	97.4	17.83
PC30536.	101	60	£7.03	80.4	16.98
PC30388.	88	53	£6.21	82.3	15.00
PC21914.	101	44	£5.15	59.8	12.46
PC30580.	89	33	£3.86	50.2	9.34
LT22515.	40	29	£3.40	97.6	8.21
LT22283.	41	27	£3.16	87.2	7.64
LT22470.	45	26	£3.04	77.7	7.36

Results and Discussion

The individual device measurements were translated into totals to arrive at a sum for the entire EUC environment as shown in Table 3. The only notable change to the individual device format was the Computer Name column becoming the 'Number of EUC systems'.

Table 3 - Data Capture Results in Total of the EUC Environment Format

Number of EUC Systems	Power Average (W)	Electricity Consumption Monthly (kWh)	Electricity Cost Monthly (£)	On Time Observed (%)	EUC Emissions Monthly (kgCO2e)
1069	36	4958	£713.95	17	1403

Power Average (W)

The total EUC device Power Average appeared consistent with expectations at 36W. This result is due to the environment consisting of 98% laptops that for many models have a 40W or 45W rating. When examined in isolation the PC power average value is 53W across the seventeen units. Although 47% higher than the laptop average, the PC measurement appeared low compared to expectations in the region of 80W/100W based on ratings published by HP, Dell and Lenovo for popular business class PCs.

Whilst existing research highlights that nameplate ratings are overstated there remained an element of doubt associated with power figure for a PC and monitor combination. Following conversations with Lakeside Software it was discovered that the software is not able to measure peripheral devices including monitors. This explained the PC power value being lower than expected as an average LCD monitor would have added in the region of 18W (27 kWh) to the results per device. The inability to measure peripheral devices was noted as a limitation of the software.

Electricity Consumption Monthly (kWh) vs On Time

The total electricity consumed in a month by the EUC estate was 4,958 kWh. The average per device consumption for the period was 4.6kWh per month. As the available work hours for the period were 198, this appeared low considering a 40W light bulb (similar to the EUC average power reading) would consume almost 11 kWh in one month if left on during work hours. As this is just over 40% higher than the EUC estate was registering, the on-time metric was examined to validate the result. The following results emerged:

- 18 devices were observed as on between 75% to 100% of the available hours
- 21 devices were observed as on between 50% to 74% of the available hours
- 64 devices were observed as on between 25% to 49% of the available hours

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- 966 devices were observed as on between 1% to 24% of the available hours

The detail at first appeared to suggest that there was very little activity attributed to nearly 1000 devices all registering under 24% on time. However, as the on-time percentage is calculated using the total available hours during the period of 720 (30 days x 24 hours) it is not a true reflection of workday use. As the council operates for 198 hours per working month on average (which is 27.5% of total hours in the period), the 17% on time translates to 61.8% (5.6 hours) of available work hours. This figure is congruent with surveys reporting the hours spent working on a business EUC device (Microsoft, 2013) and therefore judged to be valid. It is therefore noted that the on-time metric is important to understanding the kWh results but arguably misleading when reported as a percentage of the entire test period time.

Electricity Cost Monthly

Understanding the cost of electricity for an EUC environment acts as an indicator of operational cost attributed to the ICT service and as a useful guide when comparing variations in price between 'standard' electricity suppliers and moving to 100% renewable energy supplier. As previously described the original electricity values were updated with the 11.71p per kWh cost to reflect the assumed location pricing paid by the council. Whilst mathematically correct, at a total of £580.58 per month to power the EUC estate, the figure could be judged invalid when scrutinised. The reason for this is that information noted during the interview suggested that 926 of the users were mobile workers.

Therefore, an as yet quantified portion of electricity could actually be consumed beyond the council premised at home or any other location. Based on average flexible working figures (Global Workplace Analytics, 2018), staff are moving to 2 days per week 'working from home' (with home representing any location). As such two fifths of the entire mobile workforce electricity cost could theoretically be absorbed by the users. If this were proven to be correct then the electricity cost monthly would need to be lowered in this instance by £201.17 (40% of the mobile workforce electricity cost). This area of doubt could be removed by creating digital personas that work with Systrack to identify mobile workers. As these workers access applications in the data centre or cloud, the persona could be tracked through Systrack, and the location (and on time) from which the user is working logged. Triangulation of this date with the total kWh per device would deliver the percentage of electricity consumed beyond the council's premised and an accurate account for the electricity cost monthly.

For price comparison between suppliers either the current electricity cost calculation or the more complex theoretical model could be used. Adding a further column to the data highlighting the difference in price between the existing and a 100% renewable energy supplier would enable the ICT or budget stakeholder to immediately visualise the cost of change. This enhancement could be seen as a positive or negative inclusion as the cost of renewable energy is often higher. As an example, the current £580.58 cost per month would rise by 40% to £999 based upon a commercial energy estimate derived directly from Ecotricity, a 100% renewable energy company. As such, an adjacent column showing the emissions abatements achieved following the change would be required to show the positive outcome.

CO_2e Calculations

The objective of is to accurately measure GHG emissions in CO_2e units based upon the kWh results. Using the method described previously, a measurement of 1,403 kg CO_2e per month for the EUC estate was calculated. Research shows that people are becoming more aware of their carbon footprint although it is arguable that the majority of EUC users would understand what the CO_2e emissions figure means in real life terms.

This is an idea that the US Environmental Protection Agency (EPA, 2019) has addressed through the development of its online Greenhouse Gas Equivalencies Calculator. The tool allows users to input emissions data which is then converted to tangible everyday items such as the equivalent car emissions

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or how many homes could be powered for one year. In these terms, the council's EUC emissions for the month tested are equivalent to 3,430 car miles. Extrapolated to one year, this equates to 16.84 tCO_2e; the equivalent of 41,174 car miles or just under four cars being driven for a year. The idea of the car miles could be included within the measuring application to visualise the individual and total emissions equivalent. This would enable both staff education plus feed into easy-to-understand CSR reports.

Whilst the CO_2e measure is mathematically correct, two factors require attention to withstand scrutiny. Firstly, the fact that all peripheral devices were excluded during measurement means that the reported CO_2e figure is theoretically lower than reality having not measured seventeen monitors. A way of overcoming this issue needs to be designed and integrated into the solution.

Secondly, the government CO_2e conversion ratio used in the experiment relates to the average CO_2e equivalent delivered by electricity in the UK grid. This metric is accepted as part of the GHG accounting protocol (GHP, 2019) and can be judged as sufficient for the purpose of mandatory emissions reporting. However, the true emissions value could be contested as market-based energy higher in renewable content would lower the CO_2e results and therefore require a manual input for the conversion rate. As an example, Ecotricity supplies predominantly wind-based electricity with a carbon intensity of 11.62gCO_2e/kWh (Ecotricity, 2018) compared to E.ON at 116gCO_2e/kWh. Should Ecotricity have been used for the EUC environment during this period of measurement, the value of carbon emissions would drop to 10% of total rendering the government published ratio invalid.

To overcome the problem would require an examination of the fungibility of electrons and determination of the CO_2e actually contained in a specific supplier's energy. Obtaining the carbon content of electricity is relatively simple following the introduction of the Electricity (Fuel Mix Disclosure) Regulations 2005 (HM Gov, 2005). This legislation, designed to promote investment in renewable energy, mandates that all energy companies publicly disclose the mix of energy sources (such as coal, gas, nuclear, wind and solar) used to generate electricity. As an example, the electricity supplier E.ON UK PLC highlights (table 4) corporate energy supply consists of 10.1% coal, 53.5% gas, 16.2% nuclear, 16.8% renewable and 3.4% other (E.ON, 2019). Understanding the mix of fuel sources indicates the amount of carbon within each fuel type in the format of grammes per kWh. In this example, E.ON suggests (see table 5) that corporate customers will have a figure of 111 g/kWh carbon content as the fossil fuel included in the electricity supply is 10.1% coal and 53.5% gas.

It is however notable that E.ON place a value of zero carbon intensity on renewable and nuclear energy. This is arguably incorrect as wind power has an estimated value of 10 g/kwh, solar power 88 g/kwh due to the carbon footprint generated during the manufacture of solar photovoltaic (PV) panels and nuclear 16 g/kWh (EDF, 2019 and Houses of Parliament, 2011). The classification of 'Other' in table 4 also highlights a carbon intensity of zero. Again, this can be challenged as the company declare that this source is from biomass (E.ON b, 2019), a fuel that has a carbon intensity of 5.6 g/kWh (Zero Carbon Hub, 2010). As such, a more realistic value for the carbon intensity of E.ON commercial electricity is actually slightly higher at 116 g/kwh.

The subject of carbon intensity being introduced to the proposed measuring application that this research relates to beyond the government ratio is debatable as electricity is fungible. As such it cannot be proven that a specific low carbon molecule of electricity will reach the purchaser and will most likely be added as an average on the grid; hence the government's approach. However, with such a disparity between the 11 g/kWh carbon content of renewable energy compared to E.ON's 116 g/kWh it is a metric worth considering.

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Table 4 - E.ON Electricity Fuel Mix Disclosure

Fuel mix	Coal	Gas	Nuclear	Renewable	Other	Total
Domestic and Small Business Customers (E.ON Energy Solutions Limited)	10.1	53.5	16.2	16.7	3.5	100
Corporate Customers (E.ON UK PLC)	10.1	53.5	16.2	16.8	3.4	100
E.ON UK Overall Average	10.1	53.5	16.2	16.8	3.4	100
UK Average	7.64	41.24	20.01	29.04	2.07	100

Table 5 - E.ON Carbon Intensity by Fuel g/kWh

Carbon Dioxide Emissions (g/kWh)	Coal	Gas	Nuclear	Renewable	Other	Total
Domestic and Small Business Customers (E.ON Energy Solutions Limited)	93	191	0	0	24	308
Corporate Customers (E.ON UK PLC)	93	191	0	0	23	307
E.ON UK Overall Average	93	191	0	0	23	307

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Recommendations

Whilst it did not cause an issue this experiment, the fact that the Systrack software does not support power and energy measurement for Android, Chrome and iOS operating systems will limit the ability to measure the total energy consumption and therefore CO_2e emissions of other, more varied. EUC environments. Considering that these excluded operating systems now represent in the region of 11% of PCs and Laptops (Statistica, 2018), and 99% of tablet devices (Stat Counter, 2018) this is a concern. As such it is advisable to seek an update from Lakeside Software as to their roadmap release plans to indicate when these devices could become supported.

The fact that Systrack does not measure monitor power and consumption is a limiting factor. In this example the impact to results could be judged negligible as only 17 monitors were excluded from 1,069 devices. However, in many LSE companies such as trading floors and call centres, one monitor per desk space is often installed. As such any future research would benefit from developing a suitable process that includes the measurement of monitors. This could be either to estimate monitor kWh based upon manufacturer published values triangulated with on time results, or through a combination of survey and power meters installed during the test phase.

Whilst complex, the introduction of true location-based electricity carbon intensity values (rather than the national average used in the experiment) may be of interest to organisations wanting to convey their CO_2e savings made by switching to 100% renewable energy. To achieve this the process would require the understanding of the CO_2e actually contained in a specific supplier's energy. It is recommended that a government ratio figure and a 'location based' figure is included in future reports for clarity.

In relation to electricity cost comparison and CO_2e abatement, additional columns showing cost to switch to renewable energy, abatements achieved, and real life CO_2e examples such as car miles should be included in future reports.

The possibility of creating and tracking job role personas should be researched. The results may assist accurate electricity cost measurement and also lead to identification of ICT related commuting emissions. As an example, a mobile worker noted to be travelling to the office may not be aware that these journeys are causing environmental pollution and that their job role allows 'working from home'.

Finally, it is recommended that the rudimentary .xls spreadsheets used in this initial experiment be developed to translate SQL data directly from Systrack into a business intelligence (BI) application such as Microsoft Power BI. In turn this dashboard would be developed to show multiple facets such as individual device data and total device data and made available via cloud access for both EUC and mobile devices. As such the results and suggested improvements relating to CO_2e could be easily accessed by company stakeholders such as those in charge of ICT, CO_2e reporting, operations and budgeting and CSR reporting.

Conclusion

Fundamentally the objective of the experiment to calculate EUC derived CO_2e emissions using analytics data was achieved. By simply translating the kWh data to a CO_2e value based on the government conversion figure, the emissions data was produced in an adequate format. However, to withstand the scrutiny of including these figures in Scope 2 emissions reports would require assumptions and statements that deal with all of the limitations and recommendations discussed above. The wider body of research that this research contributes to is focused not only on the identification of EUC emissions but also to make the reporting simple, scalable, informative and highly accurate. Therefore, the process needs considerable development in relation to the limitations and recommendations documented.

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Based on the findings and recommendations it is judged that this is feasible through further research that will tackle not only technical barriers, but also obstacles such as ignorance and indifference to ICT’s contribution to climate change.

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