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Determining the impact of information technology greenhouse gas abatement at the Royal Borough of Kingston and Sutton Council

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Abstract

Personal computing generates 1% of global greenhouse gas emissions created by the production, use and end of life treatment of devices such as desktop computers and notebooks. Consequently, legislation exists to encourage organisations to procure computers with a low total carbon footprint. The rationale being that both scope 2 use-phase and scope 3 supply chain emissions can be reduced in the long term to contribute to wider reaching abatement targets. However, research finds that current computer product carbon footprint information is both insufficiently available and inconsistent to enable such a strategy. Further research determines barriers including associated incremental cost and perceived impact also prevent the diffusion of sustainable computing strategies. As such, the case study objective is to examine the impact of overcoming such limitations and barriers within an organisation subject to both the new legislation and a holistic climate emergency. By doing so the research question, 'Can meaningful representation of end user computing carbon footprint data drive human behavioural changes to abate greenhouse gas emissions?' is answered. Conducted over 3-years using newly developed methodologies, end user computer related emissions are quantified within a Greater London Council. Presented in a format reflecting the triple bottom line of corporate and social responsibility accounting, values for planet, people and profit are defined using standard emissions units, environmental equivalents, a per capita ratio and monetary savings. Subsequent behavioural changes driven by access to the new information are fourfold. Firstly, adoption of low energy devices reduces annual scope 2 emissions by 15,841 $kgCO_2e$. Secondly, extended device retention periods displaces 515,190 $kgCO_2e$ of supply chain emissions. Thirdly, a new technology enabled remote working scheme is justified and adopted, avoiding 4,516,584 $kgCO_2e$ of commuting emissions. Finally, new computer procurement assessment practices are adopted to ensure ongoing abatement is maximised and compliance with legislation exceeded. Consequently, the council responds to the climate emergency strategy via the newly proven sustainable end user computing strategy by reducing energy consumption, waste and contributing to sustainable transport. In total, related emissions are reduced by 39% per year whilst saving £228,418 annually. As such, it is proven that the barriers of cost and perceived impact are surmountable and significant emissions abatement achievable when presented with meaningful information that drives behavioural change.

Keywords: Computer carbon footprint; computer energy efficiency; human-computer interaction; computer greenhouse gas emissions.

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1. Introduction

Generating 1% of global greenhouse gas emissions, end user computing is recognised as both a significant contributor to global warming and a potential source of abatement [1-8]. Consequently, new national and regional computer procurement legislation exists [9-11] to reduce the long term carbon footprint created by the annual manufacturing and ongoing use of over 450 million new desktops, notebooks and tablets [12-14]. Specifically, public sector organisations in the United States, Europe and the United Kingdom [9-11] are now required to purchase only computers certified by internationally recognised eco-labels [15, 16] and energy efficiency standards [17], such as Energy Star, EPEAT and TCO. As the two combined certifications are designed to reduce both supply chain and use-phase greenhouse gas emissions, the rationale is that by identifying and procuring certified computers, an organisation's total end user carbon footprint will be reduced as devices are replaced. However, whilst legislative compliance can be achieved by following the guidelines, the effectiveness of the strategy and abatement realised is not substantiated. This is because products awarded the third party certification labels vary significantly even within one device type. As an example, existing research [18] notes that two notebooks bearing both EPEAT and Energy Star certification have comparative greenhouse gas emissions values of 138 $kgCO_2e$ [19] and 809 $kgCO_2e$ [20]. As such, it is feasible for an organisation to mistakenly transition from the lower impact device to the higher impact device unless more stringent examination is undertaken.

Research also highlights that gathering data to enable meaningful comparison of end user computing devices based upon their environmental impact is limited and complex [18]. As an example, only 22% of devices have a published carbon footprint report and of these, the use phase data is presented using differing approaches that cause the data to be incomparable [18]. This is due to variables such as the carbon intensity factors used to represent the region of use and the number of years of use being incongruent. Additionally, further research identifies that the electricity consumption values used to populate carbon footprint reports are based upon Energy Star benchmark data that does not include the active use of the computer [21]. As such, the energy consumed whilst the computer is conducting useful work is not included in the published typical energy consumption value. The impact of this is that differing operating systems exhibit varied power draw requirements causing the published energy consumption values to be incorrect by a range of -48% to +107% [21]. Such complexity creates barriers to the diffusion of sustainable information technology (IT) practices such as identifying devices with the lowest carbon footprint and reporting related ongoing emissions [22]. The key reasons given are cost and time associated with overcoming the complexity plus the perceived impact and contribution of IT to an organisation's overall corporate and social responsibility strategy [22]. Consequently, inertia is created as IT teams are unable to prove the importance of sustainable computing to executives tasked with abating and reporting operational greenhouse gas emissions [22].

Joining a total of two hundred and eighty-two United Kingdom councils [23], the Royal Borough of Kingston Upon Thames and Sutton Council declared a climate emergency in June 2019 [24]. Already subject to the public sector specific collective greening government commitments [25-28] designed to recognise the environmental, social and financial benefits from greener operations, estate management and procurement, the council were more recently subjected to the Companies Act 2013 amendment [29]. Specifically, from April 2019 all public sector organisations were included alongside large commercial organisations already required to report and abate organisational greenhouse gas emissions. Consequently, the new climate emergency strategy was designed to examine areas of potential improvement including energy reduction, waste, sustainable transport and ultimately improving air quality in the surrounding area. Speculating that IT may be able to contribute to the new strategy but unable to prove it, the council contacted technology suppliers to explore possibilities. Via a mutual connection it was indicated that ongoing research at the University of Warwick [18, 21, 22, 30-36] would be capable of determining the impact of information technology greenhouse gas abatement at the Royal Borough of Kingston and Sutton Council. As such, the following sections discuss the methodology and results from a subsequent impact case study spanning a time horizon of 3-years from late 2019 to early 2022.

2. Method

The objective of the research is twofold. Firstly, to determine the abatement impact delivered by recent changes made to the IT estate within the council that may already be contributing to the climate emergency imperatives. Secondly to determine if presenting these results in a meaningful way together with further suggested improvements influences future policies such as IT procurement and operations. The goal being that sustainable IT becomes substantiated to both significantly support wider public sector net zero aspirations and capable of long term

behavioural changes that will reduce societal emissions. To achieve this the methodology involves both qualitative and quantitative research techniques and consists of five key stages. The first is to document a baseline of how IT is currently selected, purchased and used. The rationale is to discover if sustainability already exists as a key criterion in the process and to explore if existing or potential behaviours may be expanded or improved upon. This is achieved by conducting an unstructured exploratory interview with key council stakeholders at the beginning of the study. The second stage uses a survey methodology developed by the associated research [18, 33] to capture asset profile data relating to the council's end user computing devices including type, make, model and quantity values. Doing so enables the third stage that uses the commercial typical energy consumption (cTEC) algorithm [34] to produce valid electricity consumption data for the devices, measured in kilo-watt hours (kWh). The fourth stage utilises the interview information and profiling data to produce the meaningful information that determines the impact of sustainable IT in both before and after scenarios. The metrics generated include scope 2 use-phase, scope 3 supply chain and employee commuting to access IT emissions values in both GHG accounting units and analogous equivalents, plus financial savings delivered by reduced energy consumption and displaced device purchasing cycles. This is achieved by using the previously developed Px3 application [35] and the dynamic carbon footprint embodied emissions database [36]. Presented to the original and further organisation stakeholders within the first three months of the study, the format reflects the triple bottom line of corporate and social responsibility accounting [37]. Specifically, the planet, people and profit values are defined to resonate with stakeholder role based needs and interests regardless of opinions related to climate change. The final stage involves a structured and filmed interview conducted at the end of the time horizon to determine if the information produced influenced IT procurement and use policies in the long term or simply acted as a compliance exercise. By conducting these five stages, determination of the impact of IT greenhouse gas abatement at the Royal Borough of Kingston and Sutton Council is made feasible.

3. Results

Located in south west London, the Royal Borough of Kingston upon Thames and Sutton Council is one of thirty-two Greater London Borough Councils [38]. Representing local government as part of the nation's public sector, the council employs 4,069 staff. Identified as key stakeholders, David Grasty, Corporate Head of Digital Strategy & Portfolio and Jason Sam-Fat, Digital and IT Commercial Manager participated in the initial exploratory interview and remained engaged throughout the case study. Aspirations to improve energy, waste and sustainable transport approaches as part of the climate emergency strategy were confirmed. However, it was agreed that beyond existing facilities and vehicle schemes, no formal sustainability policy had yet been applied directly to IT. The rationale for the omission was because the team speculated that computing may have an ability to reduce greenhouse gas emissions, although it was deemed not feasible to substantiate the notion due to limited available product carbon footprint data. Discussions identified that current computer procurement was led by technical specification, user requirement and budget, followed by procurement teams being offered a number of models to proceed with. Whilst trying to limit the receipt of excess packaging to address unnecessary waste, the only other element of environmental efficiency undertaken was to ensure selected computers are Energy Star certified. When asked if IT emissions were quantified annually to assist with compliance reporting, it was confirmed that they were not. When asked specifically how the greening government policies [39] are responded to, the team referred back to the Energy Star initiative confirming that meaningful sustainability criteria did not currently influence IT procurement or operational behaviour. During the meeting metrics such as device retention and remote working capabilities were explored in order to identify further areas of improvement. The council confirmed that computers were retained for 5-years years and displays for 7-years, whereas despite a virtual desktop solution being in place to accommodate legacy applications, little or no remote working was currently exercised.

3.1 Asset and use profiling

During the initial interview it was explained that the end user computer estate had recently been transitioned from predominantly Microsoft Windows devices to Chrome OS devices. As previous research identifies Chrome OS devices as being more energy efficient in the field [21] and the majority of the new computing estate was not due for replacement for several years, the council requested that the current energy saving compared to the old computers be established. The rationale being that the ongoing annual utility saving and concomitant emissions reduction will contribute to the energy reduction objective of the climate emergency and may influence changes in procurement behaviour for the future if emphasised. As detailed in table 1, the summary changes between the two estates include 3,880 Windows notebooks becoming 3,700 Chromebooks and 180 Windows notebooks. Whilst 800 Windows

desktops become the equivalent number of Chromeboxes. As such, the Microsoft operating system is reduced from 100% presence to 4% following the transition. Notably, the 3,584 peripheral displays remain unchanged in both instances.

The current end user computing estate consumes 37.6% less energy per year than the legacy estate (table 1). As anticipated [21] this is due to the new Chrome OS installed devices being more energy efficient than the legacy Windows counterparts. Specifically, the Chromebooks are 40% more energy efficient than the previous Windows notebooks. Additionally, the new Chromeboxes are 84% more efficient than the legacy desktops. Whilst the displays remain identical in both instances, a further 6.3% reduction is also achieved within this device type due to the Chrome OS power management settings. The reason being that the standard display transition to sleep for Windows operating systems is 15 minutes compared to Chrome OS being 8 minutes. The least efficient computer within the current estate is the new Dell Latitude 7400 notebook consuming 46% more electricity than the Acer Chromebook 14 that replaces the Latitude 5450. Representing 180 units, this device generates 3% of the current estate electricity consumption despite being only 2% of the total unit quantity. Consequently, had the council migrated entirely to Chrome OS devices a further 1% energy saving would have been achieved. Ensuring the most energy efficient computers are identified is important as IT is now the second largest consumer of commercial electricity [40]. Based upon the council's current procurement practice, had the devices been evaluated for sustainability criteria using only the Energy Star typical energy consumption data then it is feasible the Dell Latitude 7400 would have been purchased in favour of the Acer Chromebook 14. The rationale being that the Dell device has a published electricity consumption value of 12.6 kWh/yr compared to the Acer device at 15.2 kWh/yr and being 21% higher [41]. However, in reality due to the operating system requiring less power draw during active use, the Chromebook consumes almost 50% less energy than the new Windows notebook. Consequently, the necessity to examine beyond the Energy Star certification is emphasised if the true impact of sustainable IT is to be determined.

Table 1. Asset profile, use profile (kWh/yr) and scope 2 GHG emissions ($kgCO_2e$) for legacy and current computer estates

	Description	Quantity	Per Unit kWh/yr	Total kWh/yr	Per Unit $kgCO_2e$	Total $kgCO_2e$
Legacy Estate	Dell Latitude 5450 Windows notebook	3,880	19	72,634	4	15,422
	Dell OptiPlex 7010 Windows desktop	800	64.73	51,784	13.7	10,995
	Acer B246WL 24” monitor	2,640	21.65	57,156	4.6	12,136
	HP 24uh 24” monitor	900	17.7	15,930	3.8	3,382
	LG 29UB67 29” monitor	44	24.08	1,060	5.1	225
	Legacy Total			198,563		42,161
Current Estate	Acer 14 CP5-471 Chromebook	3,700	11.34	41,958	2.41	8,909
	Acer CX12 Chromebox desktop	800	10.58	8,464	2.25	1,797
	Dell Latitude 7400 Windows notebook	180	21.12	3,802	4.48	807
	Acer B246WL 24” monitor (Chrome	2,460	20.29	49,913	4.31	10,598
	Acer B246WL 24” monitor (Windows)	180	21.65	3,897	4.6	827
	HP 24uh 24” monitor	900	16.59	14,931	3.52	3,170
	LG 29UB67 29” monitor	44	22.57	993	4.79	211
	Current Total			123,958		26,320

3.2 Greenhouse gas emissions

The study quantifies three sources of greenhouse gas emissions in order to determine current and potential abatement impact. Scope 2 relates to use-phase emissions and contributes directly to the council’s focus on energy reduction. In context, adopting more energy efficient devices will reduce concomitant emissions. Scope 3 supply chain emissions focus upon the carbon footprint created by device manufacturing. Retaining devices for longer periods displaces and reduces scope 3 emissions by extending the period between purchasing a new device. Additionally, selected new devices with the lowest embodied carbon footprint will also contribute to supply chain emissions abatement and ultimately the imperative of achieving waste reduction. Scope 3 commuting emissions are related to IT by computer services enabling increased levels of remote working. In doing so, the objective of sustainable transport adoption is supported by means of reduced car travel.

Scope 2 emissions are calculated by multiplying the previously determined kWh/yr value by a government published conversion factor that represents the carbon intensity of the associated national grid [42]. As such, the scope 2 use-phase energy emissions are reduced by the same percentage as the energy results (37.5%) from 42,161 $kgCO_2e$ to 26,320 $kgCO_2e$ creating an abatement of 15,841 $kgCO_2e$ per year (table 1).

Examining computers as a source of abatement is important as IT hardware contributes to 14% of all European waste electrical and electronic waste [43]. In order to enable the calculation of both strategies manufacturing, delivery and end of life management greenhouse gas emissions data must be available via product carbon footprint reports. As highlighted in prior research [18] Acer, the brand predominantly chosen by the council, did not at the time of the assessment produce product carbon footprint reports. This omission was pointed out to the case study stakeholders and a gap analysis conducted in order to overcome the issue. In the short term, the potential of extending device retention was conducted using averages generated by the earlier research [18] with the exception of the Dell notebook that has an available report [44]. In relation to the initial displacement theory, the council confirmed that the standard current retention period for computers was 5-years and 7-years for displays. Based upon existing research suggesting longer periods of ownership are feasible [32, 45-47], an extension of 3-years was suggested for all devices. The rationale being that as the new operating system provider Google offers software updates for a minimum of 8-years and most applications have transitioned to being browser based then, issues of future incompatibility would be reduced causing the strategy to be viable. As highlighted in table 2, the strategy is applied to the current estate and determines that 986,735 $kgCO_2e$ or 34% of scope 3 supply chain emissions are avoidable by adopting the displacement scheme. The rationale being that the embodied emissions are spread across additional years and new emissions are not required for a further 36-months.

Table 2. Scope 3 supply chain GHG emissions ($kgCO_2e$) abatement delivered by displacement and sustainable selection

Description	Quantity	Current Per Unit Scope 3 $kgCO_2e$	Current Total Scope 3 $kgCO_2e$	Total Displace Saving $kgCO_2e$	Lowest Unit Scope 3 Available $kgCO_2e$	Feasible Selection Saving $kgCO_2e$
Acer 14 CP5-471 Chromebook	3,700	300	1,110,000	416,250	102	732,600
Acer CX12 Chromebox desktop	800	341	272,800	102,300	140	160,800
Dell Latitude 7400 Windows notebook	180	294	52,920	19,845	102	34,560
Acer B246WL 24” monitor	2,640	417	1,100,880	330,264	253	432,960
HP 24uh 24” monitor	900	417	375,300	112,590	253	147,600
LG 29UB67 29” monitor	44	417	18,348	5,504	300	5,148
Scope 3 Supply Chain Total			2,930,248	986,753		1,513,668

In relation to potential future reductions to supply chain emissions achieved by selecting devices with low embodied emissions, the prior research findings [18] were again utilised where Acer data was not available. Specifically, the lowest embodied carbon footprint value for each device type was compared to the averages used in the displacement representation. As highlighted in table 2, the feasible scope 3 emissions avoidable if the council were to replace the entire estate in the future is 52% or 1,513,668 $kgCO_2e$. The reduction is predominantly delivered by the notebook selection based upon the Microsoft Surface Laptop 3 that has an embodied value of 102 $kgCO_2e$ [19] compared to the average used in the prior example of 300 $kgCO_2e$ [18]. This highlights that examining beyond the compliant certification level within device types [15, 17] can reduce emission by as much as 66%.

Focusing on sustainable strategies for transport is important as the pollution source is responsible for 14% of annual global emissions [48]. Specifically, commuting is a considerable contributor in the United Kingdom, being responsible for 27% of all journeys with 68% conducted by car [49]. In the context of the council and end user computing, creating a flexible working policy for users supports the concept of reduced commuting. It was noted during the interview and asset profiling exercise that the council already used a Citrix virtual desktop solution in order to manage legacy application incompatibility. It was discussed that the stakeholders would like to investigate the impact of expanding this solution to enable remote working. As such it was agreed that the concept would be included in the research to highlight the feasible contribution to the council's sustainable transport element of the climate emergency strategy. In order to examine the environmental impact, emissions relating to employees driving to work are calculated. The rationale being that alternative methods of transport such as buses and trains will operate regardless and as such will not deliver pollution reduction caused by the council's remote working policy. As no specific data is available relating to council employee commuting, it is assumed that each employee will complete a

return journey of 18.2 miles per day [49] and work 232 days as per national statistics [50, 51]. Vehicle carbon intensity is based upon an average car as published by the United Kingdom Government [42]. Consequently, employing 4,069 people, it is suggested that 2,767 (68%) travel to work by car [49] five days per week. Therefore, annual employee car commuting mileage is calculated as 11,683,38 and creates 3,224,146 $kgCO_2e$ of emissions. Using the end user computing remote working solution to enable employees to work from home for two days per week compared to the current 5-days working from the council offices, reduced this value by 40% to 1,931,708 $kgCO_2e$ avoiding 1,292,438 $kgCO_2e$.

3.3 Meaningful representation of end user computing carbon footprint data

Associated research determines that barriers such as cost and perceived impact are limiting the diffusion of sustainable IT practices within the United Kingdom service sector [22]. As such, it is important that the data generated by the study is presented to council stakeholders in a meaningful way that will appeal to role based needs in order to help overcome these barriers and justify adoption. From a planet perspective, the electricity consumption, supply chain and commuting greenhouse gas units are presented in two forms. The first is the $kgCO_2e$ unit measurement required by international accounting and reporting protocol [52]. In this format, the results will appeal to those managers and executives tasked with compiling the now mandatory emissions values for annual company reports [29] and planning abatement strategies. The second representation uses equivalent values to ensure the impact of emissions figures immediately resonate. These include real life tangible statements translating the accounting values to the equal amount of pollution created by car miles or an area of forest required to sequester the emissions. From a people perspective, a value called the equivalent value per employee (EVE) ratio is included [53]. Primarily, this is designed to express a direct correlation between changes in behaviour in relation to an employee's IT related carbon footprint and pollution. Specifically, EVE is a per capita ratio based upon the number of equivalent polluting car miles associated with a computer single user. Calculated by determining the annual combined emissions from scope 2 device electricity consumption, scope 3 embodied device emissions and scope 3 commuting to access IT emissions, the individual and collective result can increase or decrease depending upon variables such as device choice, retention and remote working frequency. As research highlights that those employees not subject to sustainability strategy formation or related key performance indicators are disengaged with climate emergency strategies [22], the concept is twofold. Firstly, to offer all employees an opportunity to participate in the impact of sustainable IT practices. Secondly, to enable human resources and IT teams an additional way in which to engage with a group that is effectively the largest stakeholder of all and often overlooked in relation to sustainability participation [22, 53]. From a profit perspective, the application produces two financial metrics in order to assist organisations to justify sustainable IT practices from a cost perspective. The first is the annual utility saving caused by both the adoption of energy efficient computing devices and the reduction of office based device electricity consumption as a result of increased remote working. The second financial metric is the annual reduction in hardware costs delivered by the extension of device retention periods. These two outputs are designed to appeal to stakeholders in operational and financial roles, emphasising that whilst the climate emergency is being responded to effectively, costs are lowered therefore causing the long term practice of sustainable IT adoption to be viable.

Planet: The new low energy devices reduce Scope 2 emissions by 37.5% creating an annual abatement of 15,841 $kgCO_2e$ (table 1). Extending device useful lifespans by 3-years reduces scope 3 supply chain emissions by 34% creating an annual displacement of 328,917 $kgCO_2e$ (table 2). Increasing remote working from zero days to 2 days per week reduces scope 3 commuting emissions by 40%, creating an annual abatement of 1,292,438 $kgCO_2e$. In total, should the council continue with the selected devices and adopt the proposed sustainable IT practises of displacement and remote working, a combined annual direct and indirect emissions reduction of 1,637,196 $kgCO_2e$ is feasible. In relation to the impact to the climate emergency overall objective of cleaner air for the borough, this is equivalent to avoiding pollution created by driving a car for 5,932,725 miles and releases the sequestration capacity of 1,964 acres of mature forest.

People: As previously described the people element of the results utilises the 'planet' greenhouse gas and equivalent emissions to create an environmental per capita ratio. Based upon the IT environmental impact of the current strategy the combined scope 2 and 3 annual emissions are 3,751,114 $kgCO_2e$ (table 1 and 2 and accounting for 5 and 7-year retention periods), equivalent to 13,592,962 car miles. This produces an EVE ratio of 1:3341 based upon 4,069 employees. Should the council adopt the suggested retention period extensions and the remote working scheme then annual IT related emissions can be reduced by 39% to 2,286,946 $kgCO_2e$ 9 (table 1 and 2). Equivalent to 8,287,237 miles, this reduces the EVE ratio to 1:2037. During the presentation stage, it was also indicated that by

additionally introducing sustainability as a criterion during selection and purchasing processes in the long term, then this value could be reduced further to 2,112,380 $kgCO_2e$ per year. Equivalent to 7,654,660 miles the EVE ratio becomes 1:1881, meaning that for every employee it is feasible to reduce pollution equivalent by 1,460 miles annually.

Profit: The annual 74,605 kWh/yr device electricity consumption reduction delivered by the new devices saves the council £8,721 per year in utility costs. Additionally, extending all device useful lifespan by an additional 3-years spreads procurement costs by delaying future purchases. The impact of this is a further annual operational saving of £213,900 via displaced procurement. Finally, should the council decide to proceed with remote working, the effect would be 40% less end user computing electricity consumption within council premises delivering a further utility cost reduction of £5,796. Consequently, it is reasonable to suggest that the concept of cost being a barrier to sustainable IT practices [22] is counterintuitive. The rationale being that a combined annual saving of £228,418 is feasible by responding to the key objectives of the climate emergency via the medium of environmentally conscious end user computing decisions.

3.4 Behavioural Change

As discussed, the objective of the research is to determine IT related abatement and to document whether longer term behavioural changes were caused by the information being made available in a meaningful format. From a council perspective, Jason Sam-Fat initially noted that*, 'The sustainability report was helpful to underpin benefits in our business case to go to Chrome, to say what we would achieve in terms of energy reduction.'* Noting the viable influence on stakeholders, the results were presented to the wider community at a Commissioners Network event and during climate emergency meetings, *'It was the first time we'd had such detailed information about our carbon footprint and it was really good that IT had significantly more information about emissions than any other department and a clear roadmap for the future'.* Grasty agreed, '*We knew at the time that the devices we were deploying were far more efficient and that the infrastructure would deliver sustainability goals but we couldn't quantify it.'* On receiving the research results, he added*, 'It's been fantastic having that benchmark and actually quantifying what impact IT has had on the overall Council's goals.'* Alluding to the council's climate emergency key objective of energy consumption reduction he commented, *'The figures have shown that we've made a tremendous difference in our carbon footprint which is something that we didn't know before. Actual quantifiable evidence to be able to say that this is what we've done has shown us that moving from a desktop Windows environment to an Acer/Chrome environment has reduced our energy consumption by a third and taking carbon out of the atmosphere every year, which is a fantastic result in itself.'*

Within two weeks of the initial presentation and subsequent feedback, the influence of the information upon behaviour became more definitive. Grasty, having accepted that it was feasible to utilise remote working to reduce employee commuting emissions, created a five-year business case justified by the data. Clearly identifying that a two day per week home working strategy would directly support the council's key climate emergency strategy of reduced transport emissions the stakeholder looked beyond the exhausted computing budget for funding. Successfully applying for financial investment from an associated climate emergency budget, an expanded Citrix remote working solution was purchased and implemented for all computer users. Anticipating the planned abatement, the results were actually far higher than expected. As the pandemic struck two months later the council were already prepared to respond. Subsequently interviewed [54] Grasty commented, *'the remote working solution enabled us to move seamlessly to more than 95% of our staff working remotely without any changes to our infrastructure, which was fantastic. The majority of our staff just took kit home and worked from home, or worked at home on their own kit until we could provision out a Council Chromebook for them.'* From an impact perspective, during the full year that the council maintained a 5-day a week remote working policy, it is determined that commuting emissions avoided during the subsequent 12-month period was 3,224,146 $kgCO_2e$. This is equivalent to the pollution created by 11,683,381 car miles. Grasty also confirmed that with a near return to normal working conditions, the original 2-day per week plan is now permanently adopted. Similarly, the council has adopted the extended retention periods and are now realising the associated abatements in line with the climate emergency objective of reduced waste. Enthused by the prospect, the council is taking additional steps to also adopt the more granular examination of device embodied emissions suggested by the research. The impact is reflected in the new device selection and procurement process now including sustainability as key criteria.

Interviewed in the Autumn, 2021 [55] Sam-Fat confirmed, *'For Kingston and Sutton the IT procurement function sits within IT, so we work very closely with the Technical Team to look at the actual best specification and then the sustainability drivers. Looking at the whole lifecycle, it's important to have all of these conversations at the start and understand how you want to procure it, lend it, and at the end of it, what do you do with that as well. So it's a cradle to grave approach and that comes down to the performance and benchmarking.'* Sam-Fat concludes that to achieve this 'walled gardens' must be removed, '*It's about taking stock of where we are and should we be doing something different. And if we are, how can we do that collectively different. For me that's what good sustainability looks like: it's to have partners I can actually equally input and be very open and honest and recognising weaknesses and strengths and actually how can we work together towards a common outcome and a goal'.*

The common goal to address scope 3 supply chain emissions reduction will be realised by examining product carbon footprint data during the selection process. Key to this is having data that is available, accurate and importantly, equivalent. Research conducted in the earlier stages of this impact value chain produced a second application designed to enable this [18]. Called the dynamic carbon footprint application [36], the online tool overcomes the lack of uniformity associated with published product carbon footprint data [18] and harmonises the results to accurately reflect variable criteria such as location of use and retention periods. Such a capability will enable the council's IT and procurement teams to assess and compare end user computing devices based upon sustainability criteria whilst ensuring parity is achieved. However, as Acer does not currently publish product environmental data both Google and Acer would not be able to participate in the council's future strategy. Fortunately, based upon the council's intention to evaluate the new tool and coupled with Google's independent verification of the associated energy reduction research [56] a behavioural change has also been experienced within the world's fifth largest computer manufacturer. Specifically, Acer has since utilised the Px3 application to create a world first end-of-life trade in scheme called Green Rewards [57] and has begun to produce product carbon footprint reports and information from 2022 onwards incorporating the methodology developed by the impact value chain research [58].

4. Summary

Whilst the evolution of the council's sustainable information practices continues, it is reasonable to summarise that meaningful representation of end user computing carbon footprint data does drive human behavioural changes to abate greenhouse gas emissions. Specifically, the realisation of the energy reduction achieved by the transition to Chrome OS products not only delivers 15,841 $kgCO_2e$ of annual scope 2 emissions it has also caused the council and its suppliers to examine the emissions source in greater detail. Further, to independent peer review from Professor Erinn Ryen, Google adopted the results of the reduced energy findings related to Chrome OS [56]. The concept now acts as the foundation pillar for the software vendor's global sustainability strategy relating to device efficiency and displacement practices. Similarly, Acer has adopted the device use phase analysis methodology used in the use profile exercise in order to represent real life customer use and associated environmental impacts for commercial and public sector companies [57, 58]. Additionally, the device manufacturer is using the approach to measure computers and displays for energy consumption in the field that may be purchased by the Royal Borough of Kingston and Sutton Council in the near future. Doing so ensures that the council continues to identify devices with the lowest scope 2 emissions impact. Furthermore, a change in behaviour towards retention periods has delivered annual abatements within the council. Now in the third year of adoption 515,190 $kgCO_2e$ of scope 3 emissions have already been displaced. Similarly, procurement practices are evolving to realise a feasible longer term reduction of embodied emissions in the region of 1,513,668 kgCO2e by comparing manufacturing, transportation and end of life processing impacts before purchase. Using the dynamic carbon footprint application [36] to present Acer's new commitment to product environmental publishing, procurement teams will be able to look beyond simply complying with legislation by selecting certified products. Considering that Acer is the world's fifth largest computer manufacturer with 6% global market share, this new willingness to produce carbon footprint data arguably substantiates the research hypothesis in isolation. Similarly, behavioural changes have been experienced at a user level, achieving an average two day per week remote working policy has cumulatively delivered 4,516,584 $kgCO_2e$ in abatement during the case study. The validation being that it was the meaningful presentation of the emissions data that enabled the funding and purchase of an expanded Citrix solution. Related to this, Citrix subsequently adopted the findings and approach used by the Px3 application as the foundation of their global customer facing sustainability strategy [59]. The simple rationale being that the impact of remote working enabled by IT is capable of reducing commuting emissions by between 20-100% depending upon the number of days included in each strategy.

5. Conclusion

This impact case study substantiates that one organisation of 4,069 users has subsequently avoided emissions totalling 5,079,297 $kgCO_2e$. Through changes in behaviour driven by meaningful sustainable IT data, the equivalent pollution generated by driving an average car 18.4m miles has been avoided. Such emissions would require the sequestration capacity of 6,095 acres of mature forest. In context, that is an area 2.4 times the size London's largest Royal Park coincidentally located adjacent to the Royal Borough of Kingston and Sutton. Considering that the abatement will be ongoing and the council is planning to share the new sustainability strategy with a further thirty-one Greater London Councils, it is reasonable to conclude that the research objectives have been positively answered and validated.

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