Px3 EUC Device Use Phase GHG Emissions

Research Paper for the Acer Chromebook Spin 713 Computer

Abstract

Information technology (IT) related activity is recognised as a high contributor to environmental pollution and climate change, directly and indirectly causing as much as 5% of global emissions [1]. The GHG sources include a EUC device carbon footprint of over 1% attributed to embodied and use phase energy (UPE) consumption [1] due to raw material acquisition, manufacturing and assembly plus the electricity required to power popular devices such as notebooks, desktop computers and tablets. As identified by this and associated research [2], the environmental impact is highly variable due to differing materials used during embodiment and the range of energy efficiency experienced between EUC devices within the same category. A further 2.5% is attributed to the carbon footprint created by employees commuting to access IT (CAIT). To determine specific levels of impact, this empirical lifecycle assessment (LCA) research examines the positive consequence of two specific IT sustainability strategies. These include the identification and adoption of energy efficient personal computers and remote working strategies enabled by mobile devices. The results find that the Acer Spin 713 Chromebook is capable of reducing scope 2 electricity consumed emissions by between 55-86% depending upon form factor. Additionally, as part of a remote working strategy, the notebook will enable between 20-100% of scope 3 CAIT emissions depending upon the number of remote working days adopted.

Introduction

Since the Industrial Revolution, human polluting activity known as anthropogenic interference has already caused 1.0°C of global warming [3]. A further increment to 1.5°C will be reached between 2030 and 2052 if emissions increases continue at the current rate [3]. However, scientists calculate that reaching and sustaining net zero global anthropogenic CO_2 emissions by mid-century, will halt global warming on a multi-decadal scale and temperature gains will begin to peak [3]. To achieve this goal, it is calculated that the world cannot rely solely on key greenhouse gas abatement strategies, such as vehicle electrification and renewable energy transition [4, 5, 6, 7]. This is because evidence indicates that the rapidity of adoption and associated abatement will not be sufficient to bridge the annual emissions gap forecast for 2030 [7]. As an alternative, scientists and governments agree that all aspects of human pollutant activity must be examined and low carbon alternatives researched and diffused during the next decade to compensate for this limitation [3].

Specifically, the United Nations Environmental Programme (UNEP) suggests that to bridge the gap, the world must combine existing technology with innovation. Doing so will support the UN Sustainable Development Goal (SDG) [8] for climate action and drive behavioural changes capable of reducing societal emissions [7].

Considering the criteria, personal computing is a prime candidate technology for participation in this alternate sustainability strategy.

The rational being that as a mature technology, end user computing (EUC) directly generates over 1% of global GHG annual emissions [1] caused by the yearly manufacturing of 460 million devices and the associated energy consumed by 4.2bn active users [1]. Indirectly, a further 2.5% is attributed to IT users commuting to access IT (CAIT) with research determining that the average user creates 1,031 $kgCO_2e$ of emissions per year [48].

Current research indicates that this annual carbon footprint is 1.95bn tCO_2e of GHG emissions. This is equivalent to the pollution generated by 7 trillion fossil fuel car miles and requires a 9.45m km^2 of mature forest to sequester the pollution [1].

Legislation as a Sustainability Driver

Global environmental frameworks [9] protocols [10] and treaties [11] have subsequently generated regional and nation GHG abatement and reporting legislation [12-18], sustainable ICT purchasing policies [19-25] and manufacturing and use standards [26-40] designed to encourage organisations to adopt sustainable IT practices. This includes a focus upon estates emissions created by electricity consumption plus supply chain and transport emissions. However, research highlights that resistance factors, such as a lack of awareness, cause over one third of organisations to simply not take action [41].

From a global perspective, each nation experiencing such inertia misses an opportunity to bridge the emissions gap as the world continues to experience digitisation. As an example, the United Kingdom's (UK) Climate Change Act [12] includes an amendment to the Companies Act [13], ensuring that organisations operating in the UK are subject to mandatory GHG emissions reporting. Specifically, from April 2019, all organisations listed on the London Stock Exchange, all large unquoted companies and large Limited Liability Partnerships (LLPs), Government departments, non-ministerial departments, agencies and Non-Departmental Public Bodies must adhere to the legislation.

These organisations, known as the 'service sector', represent over 50% of the total national workforce with 10.74m working in large companies and 5.4m in public organisations [41, 42]. The sector consumes 32% of all UK electricity with 10.4% attributed to the use of IT solutions [41, 42].

Consequently, information technology (IT) is the UK service sector's third largest consumer of electricity behind lighting (14.5%) and cooling and ventilation (13.4%) [41, 42].

To directly address this growing GHG source, specific conditions are included within national and international legislation requiring EUC device procurement and subsequent operation to meet what are described as 'hard targets' [1, 22]. These include all future IT purchases to be accompanied by a scientific targets capable of supporting GHG abatement and net zero initiatives. In response, this could be as simple as selecting EUC devices proven to have a low carbon footprint driven by influences such as energy efficiency. The rational being that the concomitant GHG emissions would therefore be reduced cumulatively during the useful lifespan of the product.

Science Based Targets

However, associated resistance factors, such as incremental budget perception, are preventing almost one third of organisations to adopt meaningful sustainable IT strategies [41]. The cause being the time associated with identifying genuinely sustainable computer equipment is considered prohibitive when triangulated with the perceived positive environmental impact that such projects deliver [41]. Such friction causes inertia within an organisation's ability to balance the triple bottom line of profit, planet and people. In simple terms, if taking climate action is perceived to be too complex and too costly, even those organisations with mature corporate and social responsibility (CSR) and environmental, social and governance (ESG) strategies fail to form truly science based targets for IT [41]. The complexity and confusion is caused by associated carbon footprint information required to enable valid environmental buying criteria being elusive, confusing and unintentionally misleading [1]. As an example, almost three quarters of companies note that in order to identify EUC device GHG emissions caused by electricity consumption, they use two methods [43]. Firstly, 39% convert the publicly available energy efficiency benchmark data to GHG emissions using government published electricity conversion factors. Secondly, 35% rely upon the manufacturer published GHG use phase emissions values to populate the reports.

In both cases, research identifies that the resulting GHG emissions values are underestimated by 30% and cause substantiated abatement opportunities in excess of 55% to be overlooked [2].

The error is caused because the energy efficiency benchmark data used as the source for both approaches only measures and reports 'no-user present' power draw and electricity consumption associated with low power modes such as 'off', 'sleep' and 'idle' [2]. Consequently, the impact of user interaction upon the computer's energy consumption performance as the device carries out useful work is excluded from any calculations. During this 'active' mode, the EUC device will consume additional electricity as it processes requests, seeking data from storage, memory, or cache and populating the screen with images. Additionally, depending upon variables such as the type of operating system (OS) and chipset, EUC device energy efficiency varies considerably during the active mode [2].

As such, the lack of clear understanding of such environmental performance metrics causes the setting of science based targets to become unfeasible [2]. As an example. the impact not only affects presales device selection but also post purchase GHG quantification and reporting. As both metrics are essential to assessing the successful achievement of sustainability 'hard targets' and GHG accounting, the importance of accessing accurate values becomes intensified. Considering that GHG accounting protocol for scope 2 (electricity purchased for consumption) emissions requires quantities of carbon dioxide equivalents (CO_2e) to be calculated as 'neither over nor under actual emissions' [45] inaccuracies of 30% cannot be ignored.

Accurate IT GHG Quantification

In order to overcome the complexity and inaccuracy associated with quantifying EUC device and sustainable working emissions [1, 2, 41, 42, 43, 44, 46, 48], Px³ utilises several unique methodologies conceived during PhD and ongoing field research. One example is the Px³ Device Use Phase Analysis (DUPA™) benchmark that bridges the information void by generating data highlighting energy performance in the field.

Specifically, the field measurement process accurately captures power draw (watts) and energy consumption values (kilo-watt hours) for EUC devices during the active mode. Two sets of data are produced during the comprehensive analysis, proven to be accurate within +/- 0.1%.

The first data set being power demand when conducting common user interactions such as productivity tasks (e.g. email and application access), content streaming and video conferencing.

The second data set includes real world user scenarios such as energy consumption during a working day that reflect accurately how a device performs when used in a business environment.

Both sets of data are published in the associated Px³ Device Use Phase Analysis (DUPA™): Active Mode and Use Phase Energy Consumption Measurement Technical White Paper.

Equipped with this valuable data, commercial and public sector organisations are able to quantify accurate use phase GHG emissions in order identify EUC devices that can support sustainability strategies via the abatement of scope 2 emissions.

As such, bridging the information void generates ‘real world data’ that enables:

- Sustainable low energy EUC device selection criteria to create procurement programmes that are both simple and meaningful [1, 46]
- Electricity cost savings to be identified in order to support sustainability projects and break resistance barriers [41, 42]
- Quantification of all scope 2 and 3 IT related EUC GHG emissions to become simple, accurate and specific [1, 2, 41, 42, 44]
- Science based targets for climate action to be formed and monitored that withstand scrutiny to support hard targets required for a net zero future [1]
- Scope 2 GHG EUC device accounting and carbon footprint reporting to become accurate in order to comply with accounting protocol [45] and associated legislation [12-18]
- Accurate EUC device GHG emissions quantification and equivalents to be included with confidence within CSR and ESG strategies to improve stakeholder engagement [1, 41, 42, 46]

Scope 2 and 3 IT Related Greenhouse Gas Abatement

Ahead of exploring real world examples determining how sustainability strategies reduce IT related carbon footprint, a brief overview of GHG accounting and categorisation is outlined as follows. The rationale being that when discussing various 'scopes' the values attributed to abatement become clear.

Carbon dioxide equivalent (CO_2e) is the accounting unit that represents a unified value for all of the greenhouse gases. The associated accounting framework called the 'Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard,' [45] offers a step-by-step guide for organisations wishing to quantify and report GHG emissions.

Including accounting for CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 using the CO_2e unit, the objective is to ensure organisations follow a standardised and simplified approach when preparing consistent and transparent GHG inventories.

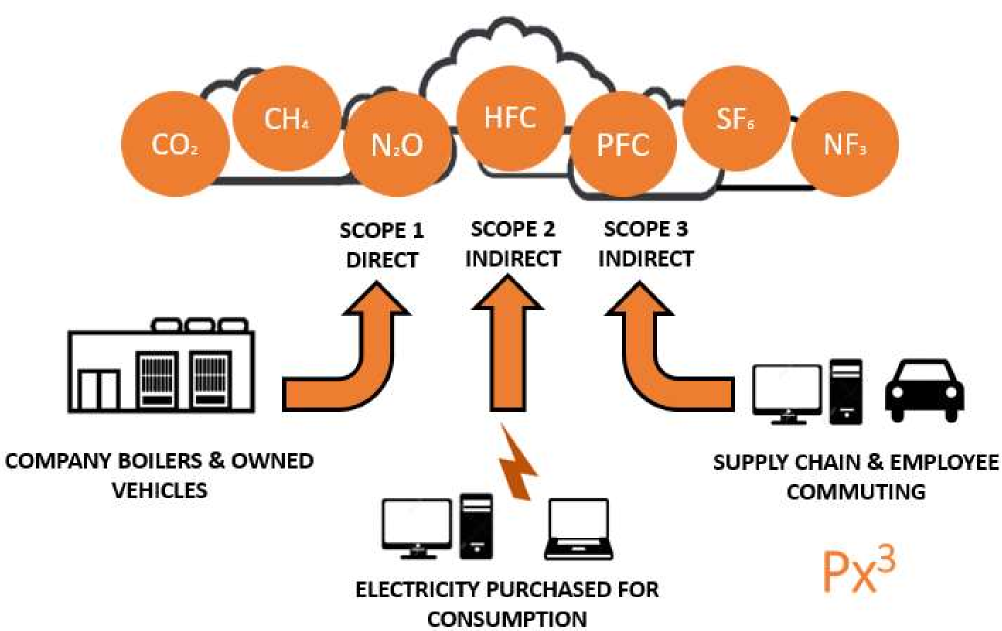
GHG emissions sources are categorised into three 'scopes' (see figure 4) to identify direct and indirect pollution generated by company operations.

- Scope 1 encompasses direct GHG emissions that occur from sources owned or controlled by the organisation. This includes emissions from company boilers and organisation owned vehicles or from chemical processing equipment.

- Scope 2 encompasses indirect emissions from electricity purchased and consumed by the organisation. In the context of IT, this includes the electricity consumed during the EUC device use phase and by data centres and networks.

- Scope 3 encompasses other indirect GHG emissions generated by activities undertaken by the organisation but not owned or controlled by the organisation. This includes activities such as the overall supply chain including IT hardware and services and employee commuting.

Figure 1 – GHG emissions by scope



As previously noted, countries are subject to global GHG reporting legislation [10-18]. This flows down to companies operating within national business markets. As an example, in the UK the necessity to report GHG emissions using the accounting protocol [45] is mandatory for all organisations listed on the London Stock Exchange, all large unquoted companies and large limited liability partnerships (LLPs), government departments, non-ministerial departments, agencies and non-departmental public bodies [14]. In relation to large companies, this is not restricted by the number of employees and companies can be judged as large if they meet any two of the following criteria [14]:

- turnover (or gross income) of £36 million or more
- balance sheet assets of £18 million or more
- 250 employees or more

Additionally, from an international perspective, public sector organisations are specifically required to adopt sustainable practices in relation to IT [20-25] that include the reduction of scope 2 and 3 emissions.

In all instances, beyond wishing to operate responsibly and tackle climate change, participation is rising because organisations are also beginning to understand that positive environmental policies create a positive influence upon both brand, prospective stakeholders and employees. As an example, 64% of millennials will not work for companies with weak CSR policies and 83% will stay with companies that contribute to environmental and social causes [41]. The opinion is further substantiated by research determining that our carbon footprint is high upon personal agendas. In a global and national study, when asked, 'If 10 is the highest importance, how important to you is reducing your carbon footprint?' the average response among employees was '8' [43, 48].

Consequently, over 60% of organisations have a CSR strategy designed to abate GHG emissions. Of these, 79% include a specific focus upon reducing IT related pollution [41].

To enable such strategies, Px[3] research focuses upon the abatement of IT related emissions in both scope 2 and 3. This includes reducing scope 2 use phase electricity consumption via the identification of energy efficient equipment. The reduction of scope 3 emissions via the identification of IT hardware with a low embodied emissions value and the justification of lifespan extension strategies such as re-purposing to drive displacement. Plus, determining the impact of remote working solutions that reduce scope 3 commuting to access IT (CAIT) GHG emissions.

This is important because, including data centre emissions, research determines [1] total IT related pollution generates as much as 5% of global GHG emissions. As an analogy, a forest the size of Canada and Greenland is required to sequester the pollution created by the way we work today.

Real World Examples

Further to the science [3, 7] legislation and policies [12-25] and accounting protocol [45] driving the need to identify sustainable IT strategies, the following scenarios offer real world examples of the associated positive environmental impacts achieved. These examples include displacement, remote working and selecting energy efficient devices. By relating IT related GHG emissions to familiar business scenarios, stakeholders wanting to bridge the emissions gap with IT related climate action can recognise the potential and embrace the opportunity. Each scenario reflects a real event proving that the results can be applied to any public or private sector organisation.

Electricity (kWh), GHG emissions (kgCO_2e) and, where relevant, financial (£GBP) values are included. Additionally, analogous values are also noted in the form of equivalent fossil fuel car miles and forest area required to sequester the pollution created by EUC operations. The rationale is to transfer meaning from a familiar object to unfamiliar values such as GHG quantification [1, 46]. As such, the 'aha' moment of consumer psychology is achieved regardless of the stakeholder's technical appreciation of either GHG emissions, climatology or computer science [46].

Two further metrics are also highlighted where relevant. These include a per capita EUC device GHG ratio known as the Px³ employee vehicle equivalent (EVE™) [1, 46] and the Px³ Silent Sole™ use phase energy efficiency EUC device certification [1]. The EVE ratio [46] achieves two outcomes. Firstly, it acts as a base line that when historically compared, enables organisations to swiftly appreciate if their EUC device emissions have proportionately improved year on year regardless of employee number expansion or contraction. Secondly, by creating an individual EUC device carbon footprint indicator, employee personal interests, needs and viewpoints are appealed to regardless of their job role or involvement with sustainability policy setting. The rationale being, that each employee becomes aware of the impact of EUC operations and has the ability to reduce the ratio by requesting and using an energy efficient device [46] or increasing remote working [48]. The ratio is created by simply dividing the 'EUC Use Phase Related GHG Emissions Vehicle Miles Equivalent' by the 'Number of EUC Device Users'. As an example, if the vehicle mile equivalent pollution for EUC use phase energy GHG emissions is 26,000 and the number of employees 1,000 then the result is 1:26. This means that for every EUC device user the equivalent of 26 miles of vehicle pollution is generated every year.

The Px³ Silent Sole certification [1] represents the number of human steps required to expend the equivalent amount of energy as consumed by the EUC device in one business day (9am to 5pm). The electricity consumption is converted to human steps for two reasons. Firstly, to achieve a universal constant as both measures are quantified in the same manner regardless of geography. As an example, if GHG emissions were used as an alternative to equivalent steps, the results would differ from country to country. This is due to the differing percentages of green, renewable and fossil derived energy that supply each nation's electricity grid and therefore affect the carbon intensity of the electricity consumed. Secondly, it is used to create a tangible analogy that can be instantly recognised and understood by all. As such, the concept of equivalent steps demystifies the often complex unit of 'kWh' applied to electricity consumption. Colour too plays a key role in certification. A green 'Silent Sole' indicates that the device is among the most efficient tested within its classification (e.g. notebook, tablet or desktop computer). Whereas amber or red indicates the device has not reached the 'green' classification threshold. In summary, devices achieving less than 1500 equivalent steps receive a green Silent Sole. Devices achieving between 1501 and 2000 equivalent steps receive an amber certification, whilst red is awarded for energy equivalent to in excess of 2001 steps.

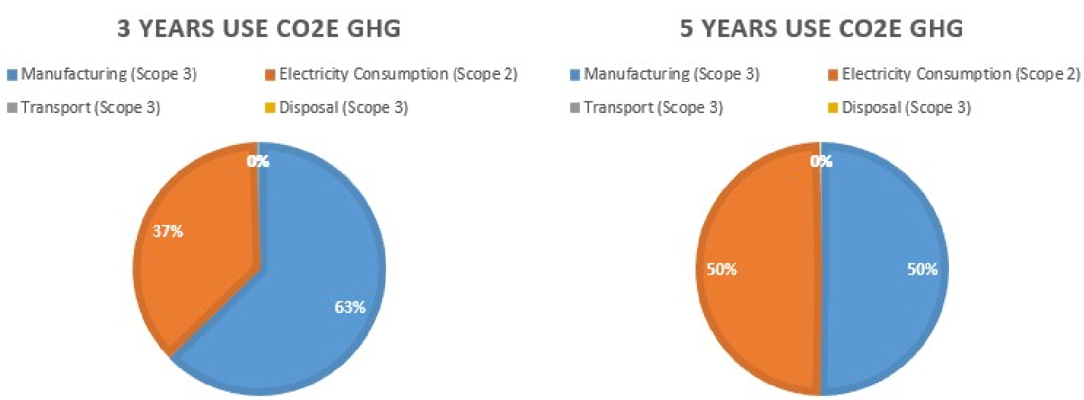
Quantifying the Positive Impact of Low EUC Device Use Phase Electricity Consumption

As indicated, embodied emissions and use phase energy emissions contribute to the majority of an EUC device's carbon footprint. Each source is accounted for as scope 2 (electricity purchased for use) and scope 3 (supply chain) respectively [45]. Often represented as a total figure in manufacturer carbon footprint reports, quantification of both measures in isolation is important if true comparison is to be achieved. As an example, one computer may appear to have a lower carbon footprint than another simply because less years of electricity consumption are included in the LCA calculation. This is best demonstrated by the lack of uniformity among manufacturer desktop computer reports. Microsoft includes a 3-year lifetime within the total carbon footprint, Apple and Dell select 4-years and Lenovo, HP and Pure Computer 5-years [1].

As such, the impact of this decision adds two extra years of electricity consumption to the product carbon foot. Figure 2 highlights this influence, showing the Microsoft Studio 2 published carbon footprint as 601kgCO_2e with 3-years of use, versus 749kgCO_2e when harmonised to 5-years. As such the proportionate representation of scope 2 energy emissions rises from 37% to 50% during the device lifespan having increased the total carbon footprint by 25%.

Understanding the effect of electricity consumption upon the carbon footprint is essential for all sustainable device procurement strategies. Electricity generation and supply remains 67% reliant upon combustible fuel despite efforts to transform to sustainable sources [6]. Consequently, energy generates 31% of global GHG emissions due to high levels of carbon intensity with electricity specifically producing 31.1bn tCO2 annually [6, 47]. Against a backdrop of global digitisation, increased electricity demand is driving the highest annual increases for more than a decade. As an example, recent annual consumption growth alone eclipsed the equivalent total emissions created by international aviation [6].

Figure 2 – Harmonising use phase energy consumption lifespan



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electricity demand is driving the highest annual increases for more than a decade. As an example, recent annual consumption growth alone eclipsed the equivalent total emissions created by international aviation [6].

As such, it is perhaps unsurprising that the majority of sustainable device procurement programmes focus upon purchasing energy efficient devices [43]. The rationale being that as the average device retention rate is between 3 and 5 years [1], then during each year of use, the organisation can rest assured that they are achieving some level of operational efficiency.

Specifically, research indicates that over 70% of organisations utilise third party certification label (TPCL) programmes, such as Energy Star, to identify energy efficient devices [43]. The strategy certainly sets a threshold for anticipated electricity consumption as such TPCL schemes are controlled by strict test set up and conduct benchmark procedures [37].

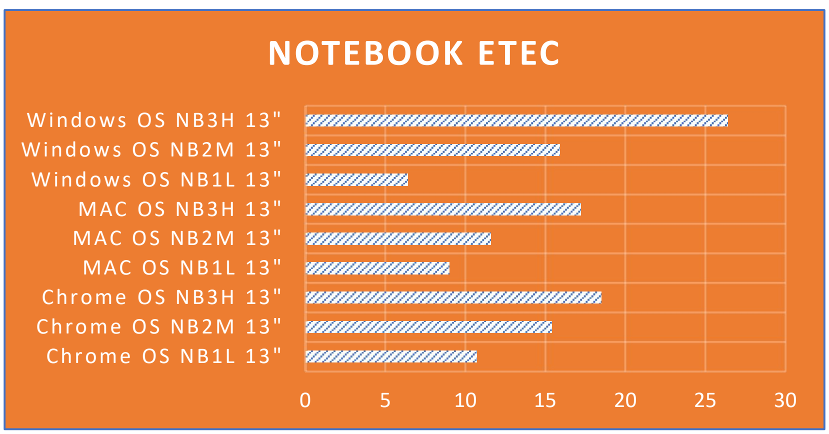
However, relying solely upon 'non-user present' benchmarks and associated identifying badges creates the potential for sustainable EUC device procurement schemes to significantly underperform [2].

This limitation is caused by two influencing factors that are often overlooked and discussed in the following two sections.

Oversight A: Range of Typical Energy Consumption Efficiency

The first issue arises simply because of the range of efficiency available by selecting EUC devices within the same category such as 'notebooks'. As an example, figure 3 highlights the Energy Star TEC values of nine commonly used business notebooks. All are similarly specified with 13" screens, span three popular operating systems and are selected to highlight a low (L), medium (M) and high (H) electricity consumption example. The range of efficiency illustrated is 0-412%, rising from 6.4kWh to 26.4kWh.

Figure 3 – Energy Star TEC Range Example



As such, it is reasonable to state that simply selecting an EUC device because it has an energy efficiency logo or certification is certainly an appropriate baseline. However, it does not ensure the maximum potential of a sustainable procurement policy if the electricity consumption values are not compared.

Oversight B: Use Phase Energy Efficiency in Business

The second issue arises because EUC device energy consumption increases when operated by a user [2]. As such, real world annual electricity consumption will not reflect the Energy Star published values [2].

The reason for this is easily explained. As previously indicated, the Energy Star energy consumption benchmark is designed to create a level playing field against which all new EUC devices can be tested for presale energy efficiency. The term 'presale' is used to describe the process as no user interaction is involved during measurement. Instead only low power, no user present modes are measured under highly accurate and well defined test set up and conduct conditions. During the benchmark power draw, measured in watts (W), is noted for operational modes including off, sleep, and idle. The results are then applied to an equation that generates a fixed annual typical energy consumption (TEC) value measured in kWh. To achieve this, time spent during one year in each mode is applied to the equation. This is called 'mode weighting'. For notebooks, the mode weightings are Off=25%, Sleep=35%, Long Idle=10% and Short Idle=30%. As such, the TEC equation is expressed as follows, where P equals 'power' and T equals 'time':

$$eTEC = 8760/1000 \times (POFF \times TOFF + PSLEEP \times TSLEEP + PLONG\_IDLE \times TLONG\_IDLE + PSHORT\_IDLE \times TSHORT\_IDLE)$$

The equation uses all 8760 hours in a year divided by 1000 to create a kWh value. In doing this it is confirmed that the 'no user present' modes apply for the entire year.

Therefore, the TEC value can only act as a real world estimation of energy consumption if a user never operates the computer.

In reality, suggesting that business computers are purchased and never operated is counterintuitive as they are designed for human productivity. Consequently, organisations must examine energy consumption performance in the field if an accurate determination of energy efficiency and electricity consumed during working hours is to be attained. Px³ measures EUC devices for energy consumption in business environments using the DUPA ™ methodology. Created during PhD research conducted under supervision of the world's leading scientific universities [1], the results enable organisations to truly select devices with the lowest environmental impact during the use phase. This is vital to climate action. This is because research substantiates that even devices exhibiting a lower published Energy Star TEC value may exceed the energy consumption of a device with a higher TEC value when used in a business environment [2]. This is directly attributed to specification aspects such as how the operating system interacts with components and applications causing more or less power draw [2].

Consequently, even organisations practising energy efficient device procurement that includes using the TEC to examine beyond the attainment of a TPCL badge, may inadvertently overlook efficiencies of up to 55% if performance in the field is not considered [2].

Energy Efficient Device Comparison

To explore the significance of including active use energy consumption to identify energy efficient EUC devices, the following scenario expresses the environmental gains that can be achieved by an organisation of five hundred employees. To allow for extrapolation, it is assumed that employees work for 232 days per year in line with government guidance [2, 17].

All kWh values used in the example are extracted from real life measurements determined during the Px³ DUPA process. Values used for the cost of commercial electricity is an average appropriate for the year of publication.

Example 1 – Selecting Low Energy Devices Reduces Cost

Organisation XYZ has 500 computer users. All current notebook devices have reached a five-year retention period and will be replaced with an appropriate new device. The organisation has decided that sustainability is a key criteria moving forward and as such energy efficient devices must be identified to support science based targets.

The organisation's legacy procurement policy required the 'purchase of devices bearing the appropriate energy efficiency third party certification label (TPCL)'. However, as part of a drive to *reduce scope 2 GHG emissions and meet new legislation, the new policy includes a focus upon selecting devices with the lowest use phase electricity consumption.*

Consequently, the organisation's legacy Windows based notebook is competing with a new Windows device and alternative Mac OS and Chrome OS devices.

Existing Windows Notebook

Using the Energy Star TEC value, the legacy Windows notebook is indicated to consume 15.7 kWh per device each year. However, based upon a real world measured annual electricity consumption the value is accurately determined to be 74% higher at 27.38 kWh per device when the active mode is included [2].

As such, the organisation's current annual electricity consumption for total end user computing is 13,690 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate is currently £1,917 per year.

Potential Replacement Windows Notebook

Using the Energy Star TEC value, the proposed Windows notebook is indicated to consume 11.4 kWh per device each year. However, based upon a real world measured annual electricity consumption the value is accurately determined to be 86% higher at 21.20 kWh per device [2].

As such, should the organisation select the new Windows notebook then the annual electricity consumption for total end user computing will be reduced by 23% to 10,600 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate would be £1,484 per year. This creates an operational electricity cost saving of £2,165 during the five-year device retention period.

Potential Replacement Mac OS Notebook

Using the Energy Star TEC value, the proposed Mac OS notebook is indicated to consume 9.8 kWh per device each year. However, based upon a real world measured annual electricity consumption the value is accurately determined to be 102% higher at 19.86 kWh per device [2].

As such, should the organisation select the new Mac OS notebook then the annual electricity consumption for total end user computing will be reduced by 27% to 9,930 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate would be £1,390 per year. This creates an operational electricity cost saving of £2,635 during the five-year device retention period.

Potential Replacement Acer 713 Spin Chrome OS Notebook

Using the Energy Star TEC value, the proposed Acer 713 Spin Chrome OS notebook is suggested to consume 14.4 kWh per device each year. However, based upon a real world measured annual electricity consumption the value is accurately determined to be 15% lower at 12.23 kWh per device.

As such, should the organisation select the new Acer 713 Spin Chrome OS notebook then the annual electricity consumption for total end user computing will be reduced by 55% to 6,115 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate would be £856 per year. This creates an operational electricity cost saving of £5,305 during the five-year device retention period.

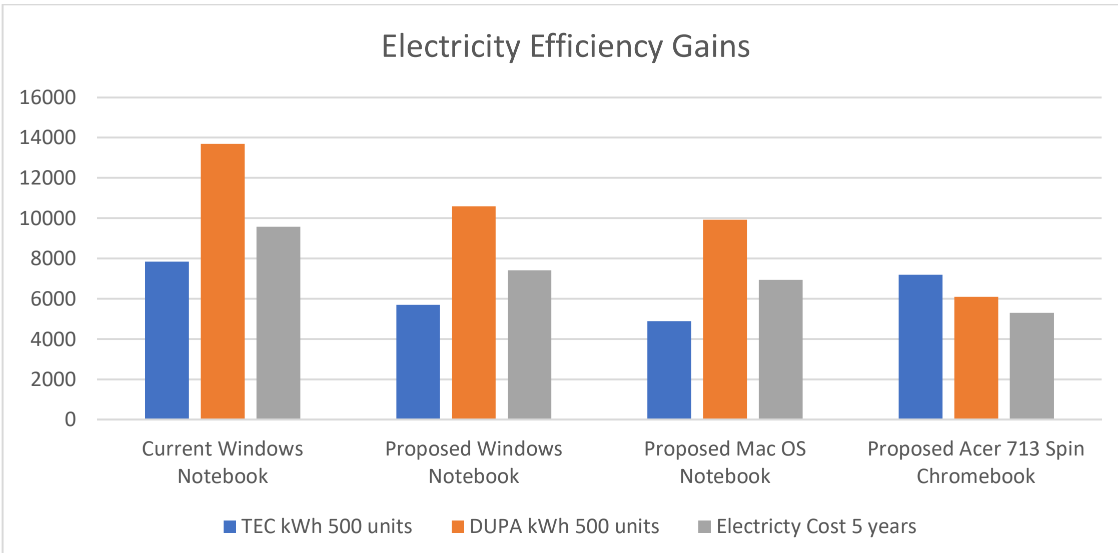
Example 1 Conclusion

It is clear that in a business environment, the Acer Spin 713 Chromebook is the correct choice to support sustainable device procurement based upon use phase criteria. Making this choice reduces both electricity consumption and cost by 55%. This represents an environmental gain with regards to GHG emissions abatement as detailed in example 3.

However, as highlighted in figure 4 (see below), it is clear that should Organisation XYZ have accepted the TEC values as an accurate reflection of EUC device energy efficiency when operated in a business environment, the full potential of the new device procurement policy would not have been *realised. This is because the electricity consumption values attributed to the no user present benchmark place the most energy efficiency business device in 3rd place.*

As such, excluding the use phase emissions from the selection criteria causes the organisation to overlook the potential of reducing EUC workplace energy consumption by 55% and prevents an electricity cost saving of £5,305 during the 5-year device retention period.

Figure 4 – Energy Efficiency Device Comparison



This is why the Acer Spin 713 Chromebook is awarded the highest 'green' level Px³ Silent Sole certification, requiring just 908 human steps per day to generate the equivalent computing use phase energy.

Example 2 – Replacing Desktops with Low Energy Notebooks Reduces Utility Costs

Organisation XYZ has 500 desktop computer users. The desktop devices have reached a five-year retention period and will be replaced with an appropriate new device. The organisation has decided that sustainability is a key criteria moving forward and as such energy efficient devices must be identified to support science based targets.

The organisation's legacy procurement policy required the 'purchase of devices bearing the appropriate energy efficiency third party certification label (TPCL)'. However, as part of a drive to reduce scope 2 GHG emissions and meet new legislation, the new policy includes a focus upon selecting devices with the lowest use phase electricity consumption.

Consequently, the organisation's legacy Windows based desktop computer and 24" monitor combination is competing with a new Windows desktop device and a Chrome OS notebook device.

Existing Windows Desktop

Currently employees use a combination of a small form factor desktop with a Microsoft Windows operating system and a 24" monitor.

Measured for energy consumption in the workplace using the Px³ Device Use Phase Analysis (DUPA) methodology, the desktop computer and monitor combination consumes 86.03 kWh annually per user.

As such, the organisation's current annual electricity consumption for total end user computing is 43,015 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate is currently £6,022 per year.

Potential Replacement Windows Desktop

Selecting a potential highly energy efficient small form factor desktop and retaining the current monitors, the DUPA measured electricity consumption per device annually will be 35.91 kWh.

As such, should the organisation select the new Windows desktop and existing monitor combination, the annual electricity consumption for total end user computing will be reduced by 58% to 17,995 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate would be £2,519 per year. This creates an operational electricity cost saving of £17,515 during the five-year device retention period.

Potential Replacement Acer 713 Spin Chrome OS Notebook

Selecting the Acer 713 Spin Chrome OS notebook to replace the desktop and monitor combination, the DUPA measured electricity consumption per device annually will be 12.23 kWh.

As such, should the organisation transition to a notebook strategy, the annual electricity consumption for total end user computing will be reduced by 86% to 6,115 kWh. At £0.14 per kWh consumed, the cost of operating the 500 user EUC estate would be £856 per year. This creates an operational electricity cost saving of £25,803 during the five-year device retention period.

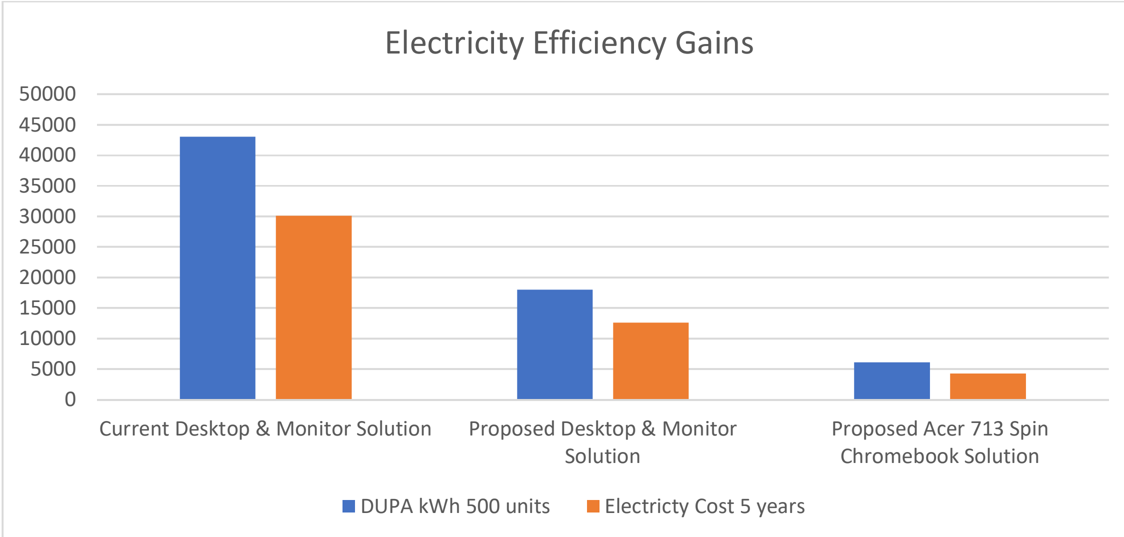
Example 2 Conclusion

It is clear that as businesses transition to 86% mobile device adoption [1], the Acer Spin 713 Chromebook is the correct choice to support sustainable device procurement based upon use phase criteria. Making this choice reduces both electricity consumption and cost by 86%. This represents an environmental gain with regards to GHG emissions abatement as detailed in example 3.

However, as highlighted in figure 5 (see below), it is clear that even when identifying highly energy efficient desktop solutions, should Organisation XYZ have retained a desktop only strategy, the full potential of the new device procurement policy would not have been realised.

As such, remaining with a desktop computer strategy causes the organisation to overlook potential EUC workplace energy consumption reduction by a further 28% to 86% and prevents electricity cost saving of £25,803 during the 5-year retention period.

Figure 5 – Energy Efficiency Device Comparison



Example 3 – Selecting Low Energy Devices Reduces Scope 2 GHG Emissions

As scope 2 GHG emissions are generated by the consumption of electricity then obviously selecting highly energy efficient EUC devices will reduce concomitant pollution. As such the following example explores the reduction achieved by both the like for like notebook replacement and the desktop computer transition previously highlighted. Again the examples are based upon Organisation XYZ having 500 computer users in each instance.

Replacing the Existing Windows Notebook with the Acer Spin 713 Chromebook

The annual electricity consumption of the existing notebook is determined as 27.38 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 13,690 kWh. As the notebooks are used within in the UK then the concomitant annual scope 2 GHG emissions value for the EUC estate is 2,906 kgCO$_2$e. This is the equivalent to the GHG emissions created by travelling 10,530 miles in an average car and requires 3.5 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user, the equivalent emissions of just over 21 car miles is generated each year to support Organisation XYZ EUC computing operations. This results in a per capita Px^3 Employee Vehicle Equivalent ratio of 1:21.

However, replacing the legacy device with the Acer Spin 713 Chromebook will reduce electricity consumption by 55% to 6,115 kWh based upon a measured 12.23 kWh per device. As the notebooks would be used within in the UK then the concomitant annual scope 2 GHG emissions value for the new EUC estate is 1,298 kgCO$_2$e. This is the equivalent to the GHG emissions created by travelling 4,705 miles in an average car and requires 1.6 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user, the equivalent emissions of just over 9 car miles is generated each year to support Organisation XYZ EUC computing operations. This results in a per capita Px^3 Employee Vehicle Equivalent ratio of 1:9.

In this example, selecting the Acer Spin 713 Chromebook reduces scope 2 GHG emissions annually by 1,608 kgCO$_2$e. This is equivalent to the pollution created by 5,826 car miles and relieves the sequestering capacity of 1.9 acres of mature forest.

Replacing the Existing Desktop & Monitor combination with the Acer Spin 713 Chromebook
The annual electricity consumption of the existing desktop and 24" monitor combination is determined as 86.03 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 43,015 kWh.

As the desktops are used within in the UK then the concomitant annual scope 2 GHG emissions value for the EUC estate is 9,133 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 33,097 miles in an average car and requires 12 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user, the equivalent emissions of just over 66 car miles is generated each year to support Organisation XYZ EUC computing operations. This results in a per capita Px^3 Employee Vehicle Equivalent ratio of 1:66.

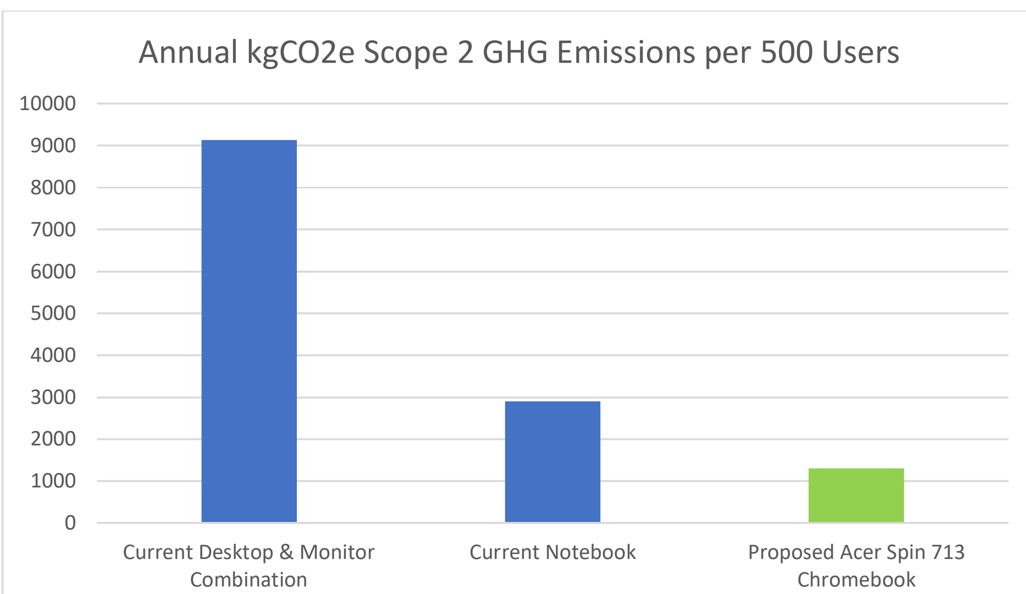
However, replacing the legacy device with the Acer Spin 713 Chromebook will reduce electricity consumption by 86% to 6,115 kWh based upon a measured 12.23 kWh per device.

As the notebooks would be used within in the UK then the concomitant annual scope 2 GHG emissions value for the new EUC estate is 1,298 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 4,705 miles in an average car and requires 1.6 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user, the equivalent emissions of just over 9 car miles is generated each year to support Organisation XYZ EUC computing operations. This results in a per capita Px^3 Employee Vehicle Equivalent ratio of 1:9.

In this example, selecting the Acer Spin 713 Chromebook reduces scope 2 GHG emissions annually by 7,835 kgCO_2e. This is equivalent to the pollution created by 28,391 car miles and relieves the sequestering capacity of 10.4 acres of mature forest.

Figure 6 – Scope 2 Annual GHG Emissions Device Comparison for 500 users



Example 3 Conclusion

As highlighted in figure 6, significant reductions in annual scope 2 GHG emissions will be achieved by transitioning to highly energy efficient EUC devices. Replacing existing inefficient notebooks with the Acer Spin 713 Chromebook it is feasible to achieve a 55% reduction. Whilst moving from a desktop environment to a 100% mobile estate will produce reductions in the region of 86%. As such, in relation to scope 2 GHG abatement, EUC form factor and energy efficiency are key criteria to successful stainable IT strategies.

Quantifying the Positive Environmental Impact of Mobile Working Strategies

Mobile working strategies involve the ability to enable employees to work from home or a similar location that is away from an organisation's premises. A consequence of adopting this approach is that associated scope 3 commuting to access IT (CAIT) emissions will be abated as staff reduce the number of days travelling to office locations. As such, mobile working practices are considering as key to sustainable IT strategies.

In the context of previous examples, relying upon fixed EUC solutions for employees, such as desktops, does not support mobile working. Empirical research [48] determines that a UK employee without flexibility will generate a scope 3 employee commuting footprint of almost 1.5 tonne of GHG emissions per year. As such, it is reasonable to suggest that transitioning to mobile solutions to create remote working opportunities will deliver positive environmental impact.

To explore this, example 4 explores a transition from 100% office working to 2 days per week mobile working.

Example 4 – Mobile Working Reduces Scope 3 GHG Emissions

Organisation XYZ has 500 desktop computer users. The desktop devices have reached a five-year retention period and will be replaced with the Acer Spin 713 Chromebook. The organisation has decided that sustainability is a key criteria moving forward and as such the impact of mobile working must be identified to support science based targets.

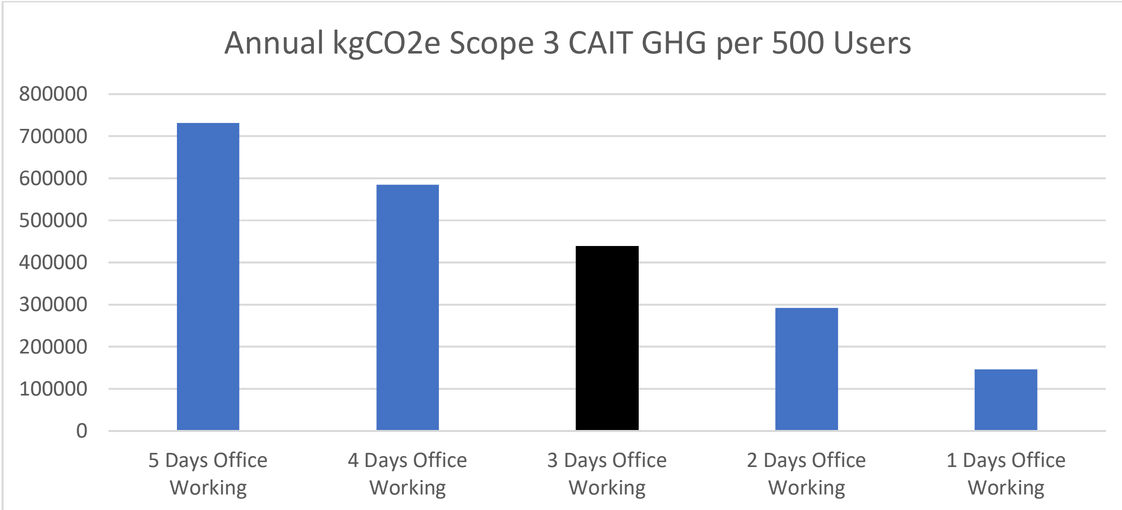
Consequently, the organisation indicates that 2 days per 5-day working will be spent 'working from home'. In doing so the new mobile working solution will reduce scope 3 employee commuting emissions by 40%.

Currently, each IT user generates 1,463 kgCO_2e GHG emissions commuting to access IT (CAIT). As such the EUC user CAIT carbon footprint is 731,500 kgCO_2e annually. This is equivalent to emissions generated by 2,650,746 car miles and requires 877 acres of mature forest to sequester the pollution.

Adopting the new strategy, the annual CAIT emissions will be 877 kgCO_2e resulting in an annual total of 438,500 kgCO_2e. This is equivalent to emissions generated by 1,588,998 car miles and requires 526 acres of mature forest to sequester the pollution.

Doing so reduces annual scope 3 employee commuting GHG emissions by 293,000 kgCO_2e. This is equivalent to avoiding GHG emissions generated by 1,061,748 car miles and relieves the sequestering capacity of s 351 acres of mature forest.

Figure 7 – Scope 3 Annual Employee Commuting Abatement for 500 users enabled by mobile working



Example 3 Conclusion

As highlighted in figure 7, significant reductions in annual scope 3 GHG employee commuting emissions will be achieved by transitioning to mobile working strategies supported by the Acer Spin 713 Chromebook. Selecting just two days working from an alternate location such as home will reduce the impact of CAIT by 40%. Obviously extending this by one additional day will increase the impact by 20% until eventually all emissions are removed in a 100% mobile working scenario. As such, in relation to scope 3 GHG abatement, switching from desktop computers to mobile form factors such as notebooks is critical to achieving single device home working solutions.

Summary

The Acer Spin 713 Chromebook is substantiated by this research as being highly suitable for sustainability strategies focusing upon the abatement of both scope 2 and scope 3 GHG emissions.

Specifically, the findings determine the notebook is capable of reducing electricity and concomitant GHG emissions by 55% in a like for like replacement scenario and as much as 86% when replacing desktop computers. Additionally, as a key component to mobile / remote working strategies the device will enable between 20-100% abatement of scope 3 commuting to access IT (CAIT) emissions.

The financial savings delivered through reduce energy consumption also challenge the notion that sustainability gains are restricted to environmental metrics [1]. As the financial examples highlight, lower energy consumption equals lower utility cost offering the opportunity to gain support from key stakeholders such as the Chief Financial or Operations Officers. Doing so enables organisations to counter the resistance factors to sustainable IT that determine cost as the biggest barrier [41].

Research also determines that the perceived impact of IT to tackle climate change diminishes among employees that are not directly involved with corporate and social responsibility (CSR) and environmental, social and governance (ESG) policy setting or subject to sustainability key performance indicators (KPI) [41]. Consequently, it is reasonable to suggest widening the appeal of IT sustainability strategies beyond such measures to a personal 'IT user' level is essential to longevity and success [1, 42, 46]. To achieve this, it is vital to ensure that outcomes driven by IT sustainability strategies are communicated in a manner that can be both easily understood and appeal to personal interests, needs and viewpoints [1, 42, 46].

Two effective strategies used within the examples to deliver simplicity and wider resonance include tangible analogy and personalisation. As previously explained and illustrated, the first is achieved by converting niche values such as GHG quantification units (CO_2e) to familiar values such as the pollution associated with car miles driven and forest acres required to 'clean' the emissions from our atmosphere via photosynthesis. The second is achieved by examining beyond the electricity utility cost reduction and GHG abatement that appeals to board level and management stakeholders and focusing the perspective to a single employee level using the Px^3 EVE ratio.

As such, the data allows for a concerted understanding of how sustainable IT can reduce environmental impact and can be used to positively influence related human behaviours such as procurement and working habits. This is important because as both legislation [12-18] and sustainable procurement and use policy [19-25] tighten causing a greater number of organisations to be subject to mandatory GHG emissions reporting and abatement, all sources of work related anthropogenic interference will be examined in the race to achieve net zero.

UNEP indicates that to bridge the gap between success and failure, the world must combine existing technology with innovation in line with UN Sustainable Development Goals such as climate action [8].

Directly generating 1% of global GHG annual emissions [1] with as much 50% attributed to EUC use [1] behavioural changes related to device selection and operation will become crucial to achieving such goals. The simple rationale being that as one one-hundredth of the total environmental problem it is hard to ignore such a rich source of abatement. Additionally, further abatement to indirect impacts such as the reduction of CAIT will assist in addressing a further 2.5% of global emissions [48] and act as part of the critical path for sustainable IT.

In conclusion, this research offers scientific quantification and substantiation to the significant abatements achievable via the diffusion of such practices.

Specifically, the findings determine the Acer Spin 713 Chromebook is capable of reducing scope 2 GHG emissions by between 55-86% and scope 3 commuting emissions by between 20-100% as part of a mobile working solution.

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About Px^3

Px^3 is a research focused IT consulting organisation specialising in sustainability and specifically the reduction of GHG emissions created by the way we work today. Our unique services enable IT manufacturers, commercial and public sector organisations to plan for and adopt sustainable IT that is good for the planet, people and productivity – hence our name.

The DUPA process is copyright of Px^3 Ltd as is the Silent Sole certification icon and EVE methodology. All three were developed during PhD research conducted under the supervision of the University of Warwick Computer and Urban Science faculty and the Warwick Business Schools Sustainability and Business faculty.

Electricity consumption values and government GHG conversion factors are accurate and current at time of measurement and subsequent publishing. Px^3 reserves the right to amend the DUPA efficiency RAG classifications as new and increasing energy efficient EUC device technology is developed and manufactured.

All measurements are conducted by qualified Px^3 research scientists and done so without bias in order to create science based data to support science based targets and sustainable behaviours. As such, energy efficiency classification is awarded solely upon data captured and results produced.

At Px^3 sustainability represents the principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations. As such, it is Px^3's mission is to remove the CO_2e emissions equivalent of 100,000 cars from our atmosphere by 2050 via the diffusion of sustainable IT hardware and services.

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