Px³ EUC Device Use Phase GHG Emissions

Research Paper for the Acer Chromebook Spin 513 Computer

Abstract

End user computing (EUC) is recognised as a high contributor to environmental pollution and climate change causing 1% of global emissions [1]. As much as one half of the EUC device carbon footprint is attributed to use phase energy (UPE) consumption [1]. The associated pollution is generated by the electricity required to power popular EUC devices such as notebooks, desktop computers and tablets when operated by a user. As identified by this and associated research [2], the environmental impact is highly variable due to differing levels of energy efficiency between EUC devices. To determine the differing specific levels of impact, this empirical research examines the positive consequence of transitioning from legacy EUC devices to a low energy EUC notebook device. Specifically, the Acer 513 Spin Chromebook is tested in relation to the abatement of UPE consumption emissions and the subsequent accuracy of defining annual GHG emissions. The results highlight that the device is capable of reducing notebook estate scope 2 GHG emissions by 61%, mixed EUC estate emissions by 70% and comparable new notebook device emissions by between 46-50%. Additionally, using the energy consumption (kWh) and GHG (CO_2e) values included within these findings, improvements as high as 74% in accuracy related to science based target setting and mandatory emissions reporting can be realised.

Introduction

Since the Industrial Revolution, human polluting activity known as anthropogenic interference has already caused 1.0°C of global warming [3]. A further increase 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

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Sustainable Development Goal (SDG) 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) generates 1% of global GHG annual emissions [1] This is caused by the yearly manufacturing of 460 million devices and the associated energy consumed by 4.2bn active users [1].

Current research indicates that this annual carbon footprint is 556,000,000 tCO_2e of GHG emissions. This is equivalent to 1.4bn fossil fuel car miles and requires a 2.8m km^2 forest the size of Argentina to sequester the pollution [1].

Legislation as a Sustainability Driver

Legislation already exists to encourage organisations to adopt sustainable behavioural changes capable of reducing IT related operational GHG emissions [10, 12]. However, research highlights that resistance factors, such as a lack of awareness, cause over one third of organisations to simply not react [8].

From a national perspective, the United Kingdom's (UK) Climate Change Act [9] includes an amendment to the Companies Act [10], 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 [11]. The sector consumes 32% of all UK electricity with 10.4% attributed to the use of IT solutions [11].

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%) [11].

To directly address this growing GHG source, the UK government's updated 'Greening ICT' policy for 2020-2025 [12] requires EUC device procurement and subsequent operation to meet what are described as 'hard targets'. These include all future purchases to be accompanied by a scientific target capable of supporting the Government plan for net zero by 2050. In response, this could be as simple as selecting EUC devices proven to be energy efficient when operated in the workplace. The rational being that the concomitant GHG emissions would therefore be reduced 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 procurement [8]. 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 [8]. 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.

The complexity and confusion is caused by the EUC device carbon footprint information required to enable valid environmental buying criteria being elusive, confusing and unintentionally misleading [1]. As an example, currently, almost three quarters of UK service sector organisations note that in order to identify EUC device GHG emissions caused by electricity consumption, they use two methods [13]. 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, without a clear understanding of power demand during use, annual typical energy consumption (TEC) cannot be calculated to reflect real world scenarios. Such an oversight causes the setting of science based targets to become unfeasible [2].

The impact from both methodologies 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' [14] inaccuracies of 30% cannot be ignored. As such, excluding the energy used during the active mode not only diminishes possible sustainable IT achievements, it also causes associated carbon footprint reporting to be both inaccurate and therefore arguably non-compliant.

Px^3 Device Use Phase Analysis (DUPA)

In order to overcome the complexity and inaccuracy associated with quantifying EUC device emissions [1, 2, 13], the Px^3 EUC Device Use Phase Analysis (DUPA™) benchmark 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 Px^3 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]
- Electricity cost savings to be identified in order to support sustainability projects and break resistance barriers [8]
- Quantification of EUC GHG emissions to become simple, accurate and specific [1]
- Science based targets for climate action to be formed and monitored that withstand scrutiny to support hard targets required for a net zero future [12]
- Scope 2 GHG EUC device accounting and carbon footprint reporting to become accurate in order to comply with accounting protocol [14] and associated legislation [10, 12]
- Accurate EUC device GHG emissions quantification and equivalents to be included with confidence within CSR and ESG strategies to improve stakeholder engagement [1]

Real World Examples

Further to the science [3, 7] legislation [10,12] and protocol [14] driving the need to adopt energy efficient EUC devices, the following scenarios offer real world examples of the associated positive environmental impacts achieved by selecting the most efficient devices. By relating the energy consumption and concomitant 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 is designed to reflect everyday organisations from both the commercial and public sectors in size and device annual use. Although the number of employees in each case is five hundred, the values can be extrapolated to suit various organisations.

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 device use. The rationale is to transfer meaning from a familiar object to a perhaps unexperienced object or experience such as GHG quantification [15]. 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 [15].

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™) [15] and the Px³ Silent Sole™ use phase energy efficiency EUC device certification. The concept of the EVE ratio [15] 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 device use and has the ability to reduce the ratio by requesting and using an energy efficient device [15]. 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.

Sustainable EUC Device Procurement Strategy

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 tCO_2 annually [6, 16]. 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].

As such, it is perhaps unsurprising that the majority of sustainable device procurement programmes focus upon purchasing energy efficient devices [13]. 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 UK service sector organisations utilise third party certification label (TPCL) programmes, such as Energy Star, to identify energy efficient devices [13]. 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.

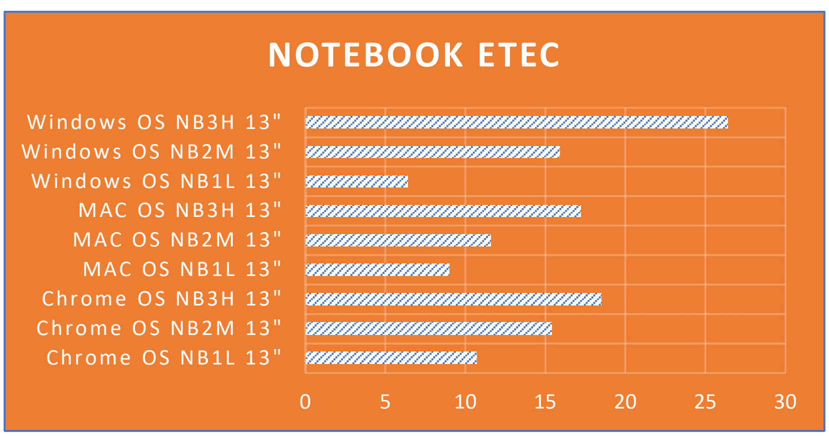
> However, relying solely upon 'non-user present' benchmarks and associated identifying badges creates the potential for sustainable EUC device procurement schemes to significantly underperform [2].

This limitation is caused by two influencing factors often overlooked.

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 1 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 1 – 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.

Scenario 1 – Quantifying the Positive Environmental Impact of Accurate Sustainable Device Procurement

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 513 Spin Chrome OS Notebook

Using the Energy Star TEC value, the proposed Acer 513 Spin Chrome OS notebook is suggested to consume 14.36 kWh per device each year. However, based upon a real world measured annual electricity consumption the value is accurately determined to be 25% lower at 10.74 kWh per device.

As such, should the organisation select the new Acer 513 Spin Chrome OS notebook then the annual electricity consumption for total end user computing will be reduced by 61% to 5,370 kWh. At £0.14 *per kWh consumed, the cost of operating the 500 user EUC estate would be £752 per year. This creates an operational electricity cost saving of £5,825 during the five-year device retention period.*

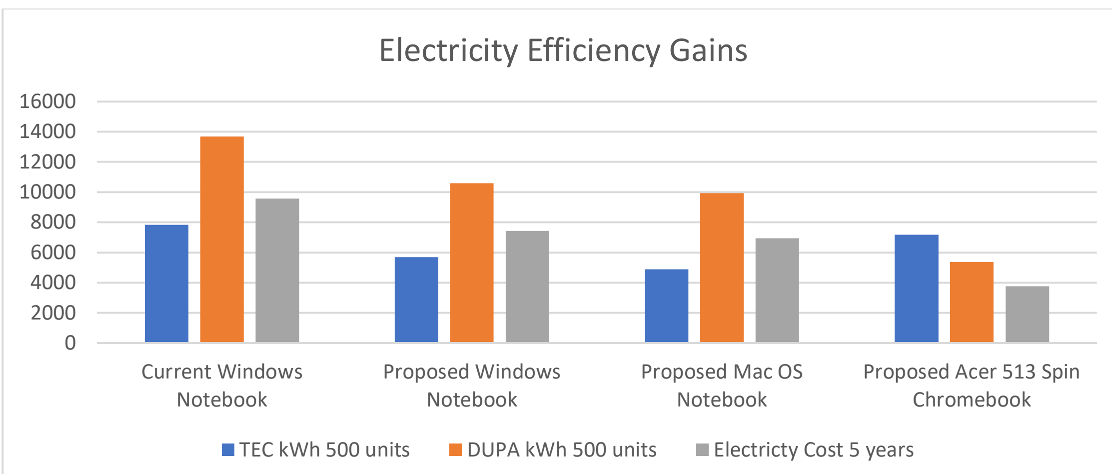
Scenario 1 Conclusion

It is clear that in a business environment, the Acer Spin 513 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 61%. This represents an environmental gain with regards to GHG emissions abatement as detailed in scenario 2.

However, as highlighted in figure 2 (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 61% and prevents an electricity cost saving of £5,825 during the 5-year device retention period.

Figure 2 – Energy Efficiency Device Comparison



This is why the Acer Spin 513 Chromebook is awarded the highest 'green' level Px^3 Silent Sole certification, requiring just 791 human steps per day to generate the equivalent computing use phase energy.

Scope 2 and 3 Greenhouse Gas Abatement

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,' [14] 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.

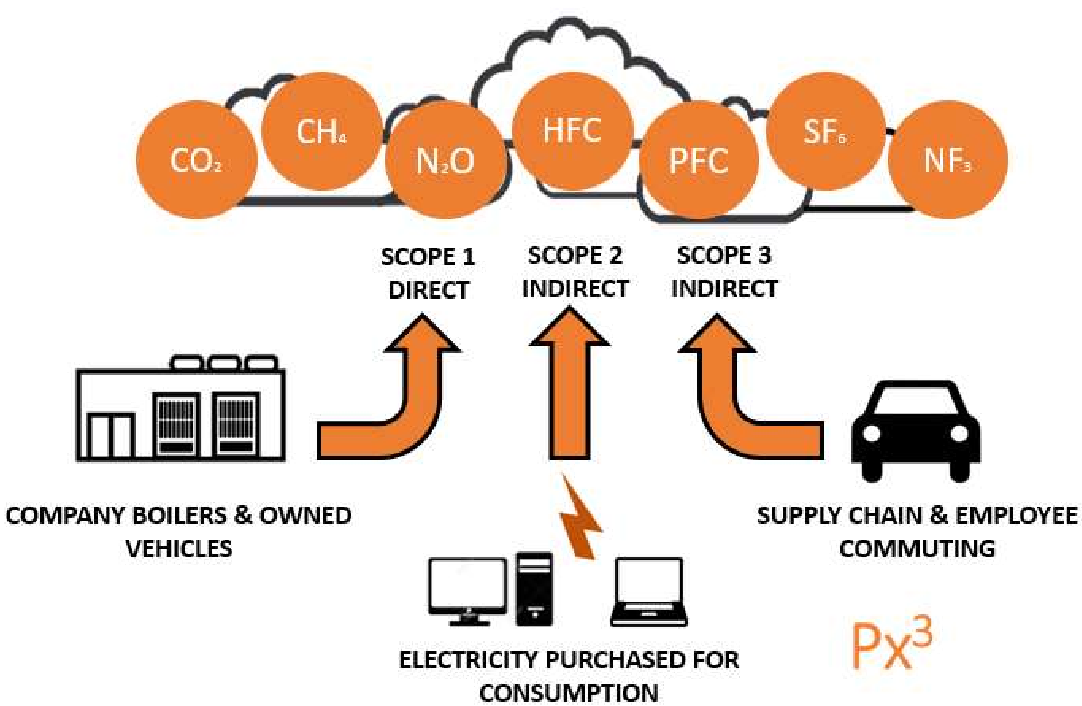
GHG emissions sources are categorised into three 'scopes' (see figure 3) to identify direct and indirect pollution generated by company operations.

- 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.

- 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 and GHG emissions from employee commuting.

Figure 3 – GHG emissions by scope



As previously noted, organisations in the UK are subject to mandatory GHG reporting [10, 18]. This includes 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 [10]. 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 [10]:

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

Additionally, public sector organisations are specifically required to adopt sustainable practices in relation to IT [12]. However, voluntary reporting is also becoming increasingly popular as part of the voluntary recommendations outlined in the UK government's Streamlined Energy and Carbon Reporting (SECR) requirements [18].

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 [8]. 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' [17].

Consequently, over 60% of organisations in the UK have a CSR strategy designed to abate GHG emissions. Of these, 79% include a specific focus upon reducing IT related pollution [8].

IT related emissions strategies include a focus upon limiting scope 2 electricity consumption. In relation to EUC devices, this is because electricity consumption represents as much as one half of all related emissions during the device useful lifecycle [1] and some devices compared to others can reduce emissions by as much as 90% depending on form factor [2].

Low GHG Device Comparison

To explore the significance of including scope 2 GHG emissions abatement as a key strategy for EUC device selection two scenarios are worthy of consideration.

The first is a transition from a mixed desktop and mobile EUC environment to an entirely mobile notebook estate. The second is the replacement of existing mobile devices with notebooks that exhibit increased energy efficiency in the field.

As such the following two scenarios define feasible environmental gains achieved by an organisation of five hundred employees in each example. To allow for extrapolation, it is assumed that employees work for 232 days per year in line with government guidance [2].

All CO_2e values represented in each instance are extracted from real life measurements determined during the Px^3 DUPA process.

Scenario 2 – Quantifying the Positive Environmental Impact of Transitioning to 100% Mobile End User Computing

Organisation XYZ has 500 computer users. In line with national statistics, global trends and associate research [1] the company has an EUC estate consisting of 20% desktop computers and 80% notebook computers. The desktops are accompanied by one LCD monitor and jointly consume 66.92 kWh of electricity per year. The existing notebooks are more energy efficient and consume 27.38kWh annually in the workplace.

All current EUC 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 to support science based targets [12] and mandatory GHG reporting and abatement [10].

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 and 3 GHG emissions, the new policy includes a focus upon two key criteria. Firstly, selecting devices with the lowest use phase electricity consumption. Secondly, moving to 100% mobility to allow for remote working to deliver a reduction in employee commuting emissions [17].

Consequently, the organisation's legacy desktop computers and notebooks are competing with a new and highly energy efficient Acer 513 Spin Chromebook.

Existing Desktop and Notebook Environment

The total annual electricity consumption value for Company XYZ's existing EUC estate is 17,644 kWh. The concomitant annual scope 2 GHG emissions are consequently quantified as 3,746 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 13,590 miles in an average car each year and requires 4.5 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user, the equivalent emissions of just over 27 car miles is generated annually. This results in a per capita Px^3 Employee Vehicle Equivalent (EVE) ratio of 1:27.

Potential Replacement Chromebook Environment

Organisation XYZ is proposing to replace the existing environment with five hundred Acer 513 Spin Chromebook devices. Based upon a real world measured energy consumption of 10.74 kWh per year per device, the total EUC annual electricity consumption will therefore reduce by 70% to 5,370 kWh.

Consequently, the concomitant annual scope 2 GHG emissions will also reduce by 70% resulting in a value of 1,140 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 4,130 miles in an average car and requires 1.3 acres of mature forest to sequester the pollution. Consequently, this means that for every computer user the equivalent emissions of just under 8.3 car miles is generated annually. This results in a per capita Px^3 EVE ratio of 1:8.

As such, having transitioned entirely to the proposed Acer 513 Spin Chromebook the organisation has reduced EUC annual scope 2 GHG emissions by 70% or 2,606 kgCO_2e. This is equivalent to preventing pollution equivalent to 9,460 car miles and freeing the environmental capacity of 3.2 acres of mature forest.

During the five-year device retention period this significant environmental gain enables the abatement of 13,030 kgCO_2e. This is equivalent to preventing the pollution produced by 47,300 average car miles.

Increased Remote Working Potential

Additionally, the transition to an entirely mobile workforce has also led to a decrease in scope 3 employee commuting emissions as employees adopt a new approach to remote working.

Research determines that when enabled, employees choose to work from home for two days per week [17] avoiding 7.4 kgCO_2e of transport emissions per person, per day [17].

As such, the new mobile environment has enabled the one hundred desktop computer users to operate from home for 40% of the working week. This means that 9,280 commuting days will be avoided each year.

Consequently, 68,672 kgCO_2e of scope 3 GHG emissions have been abated annually meaning that 82 acres of mature forest are no longer required to sequester the IT related pollution.

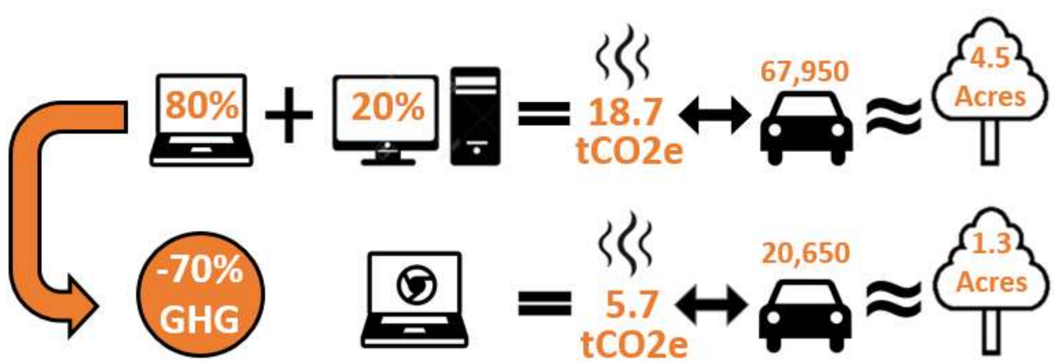
Scenario 2 Conclusion

It is clear that in a mixed device business environment, the Acer Spin 513 Chromebook delivers significant scope 2 GHG abatement, reducing emissions by as much as 70% annually due to low energy consumption during the use phase.

Additional benefits of moving to an entirely mobile EUC environment can also drive down scope 3 employee commuter emissions depending upon remote working adoption rates among those workers previously unable to 'work from home'.

As such, in this example it is feasible to abate scope 2 emissions during a five-year period by as much 13,030 kgCO_2e and scope 3 employee commuting emissions by 343,360 kgCO_2e. This is equivalent to preventing the pollution created by 1.29m car miles.

Figure 4 – Scope 2 EUC device transition for 5 years



Scenario 3 – Quantifying the Positive Environmental Impact of Transitioning to Energy Efficient Mobile Computing

Organisation XYZ has 500 computer users all of whom use a notebook computer to facilitate their job role. 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 low GHG use phase emissions 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, the new policy includes a focus upon selecting devices with the lowest use phase electricity consumption and therefore the lowest concomitant scope 2 GHG emissions.

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

The legacy Windows notebook annual electricity consumption in the workplace is 27.38 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 13,690 kWh. Consequently, the concomitant annual scope 2 emissions are 2,906 kgCO_2e.

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.

Potential Replacement Windows Notebook

The proposed preplacement Windows notebook annual electricity consumption in the workplace is 21.20 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 10,600 kWh. Consequently, the concomitant annual scope 2 emissions are 23% lower at 2,251 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 8,150 miles in an average car and requires 2.7 acres of mature forest to sequester the pollution.

As such, should the organisation select the new Windows notebook then the annual scope 2 GHG emissions will be reduced by 0.65 tCO_2e. During the five-year device retention period this will abate 3.25 tCO_2e equivalent to the pollution produced by driving 11,777 miles.

Potential Replacement Mac OS Notebook

The proposed preplacement Mac OS Notebook annual electricity consumption in the workplace is 19.86 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 9,930 kWh. Consequently, the concomitant annual scope 2 emissions are 27% lower at 2,108 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 7,640 miles in an average car and requires 2.5 acres of mature forest to sequester the pollution.

As such, should the organisation select the new Mac OS notebook then the annual scope 2 GHG emissions will be reduced by 0.79 tCO_2e. During the five-year device retention period this will abate 3.95 tCO_2e equivalent to the pollution produced by driving 14,313 miles.

Potential Replacement Acer 513 Spin Chrome OS Notebook

The proposed preplacement Acer 513 Spin Chromebook annual electricity consumption in the workplace is 10.74 kWh per device. As such, the organisation's current annual electricity consumption for total end user computing is 5,370 kWh. Consequently, the concomitant annual scope 2 emissions are 62% lower at 1,140 kgCO_2e.

This is the equivalent to the GHG emissions created by travelling 4,130 miles in an average car and requires 1.3 acres of mature forest to sequester the pollution.

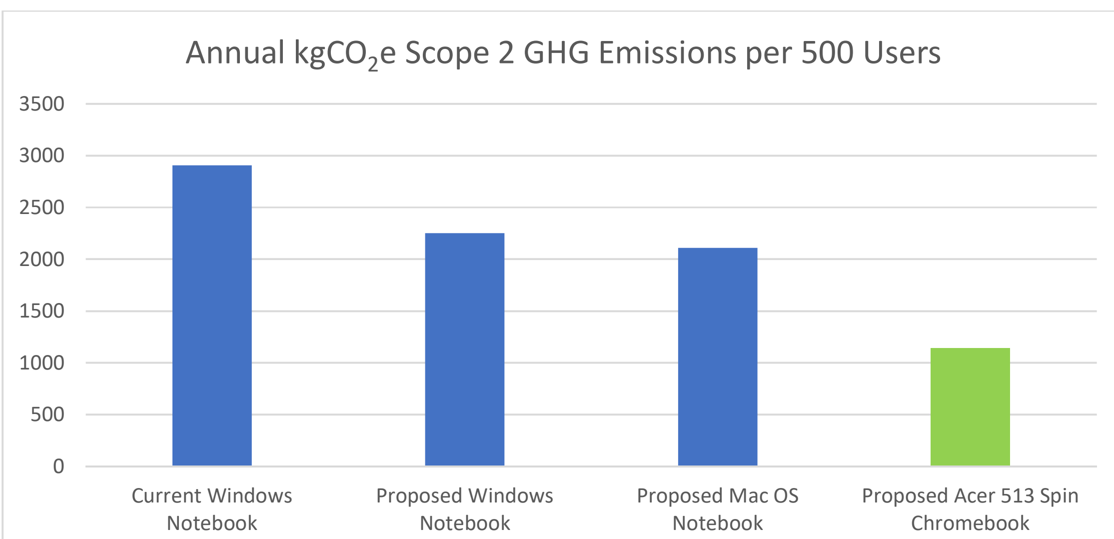
As such, should the organisation select the new Acer 513 Spin Chromebook then the annual scope 2 GHG emissions will be reduced by 1.8 tCO_2e. During the five-year device retention period this will abate 9 tCO_2e, equivalent to the pollution produced by driving 32,613 miles.

Scenario 3 Conclusion

It is clear that in a business environment, the Acer Spin 513 Chromebook is the correct choice to support sustainable device procurement in order to reduce GHG emissions. Generating annual abatements of between 62-70% for the use phase depending upon the current blend of EUC devices, the Chromebook outperforms comparable legacy and new devices.

During a 5-year device lifecycle, low use phase emissions will deliver between 1.8 and 2.65 tCO_2e in GHG abatements reducing the per capita EUC EVE footprint from 1:21 equivalent miles per user to 1:8.

Figure 5 – Scope 2 Annual GHG Emissions Device Comparison for 500 users



Science Based Targets and Accurate Scope 2 Greenhouse Gas Accounting

Science based targets and GHG accounting both require accuracy in order to ensure associated results withstand scrutiny. As previously noted, GHG accounting protocol [14] states that all quantifications must 'neither over nor under actual emissions'. Similarly, the government's 'Greening ICT' policy for 2020-2025 [12] requires that science based targets must be validated to ensure that they contribute meaningfully towards ensuring global warming does not rise above 1.5°C and net zero is achieved by 2050.

Consequently, both values must be created using data that is proven by methodology to be the most accurate among available practices. As an example, if an organisation is proposing to reduce EUC device emissions by a set percentage, the company must be confident that the baseline measurement of current emissions is correct in order to ensure that improvements and future abatements can be substantiated.

Px[3] research determines that organisations subject to mandatory GHG reporting [10] and sustainable ICT policy [12], predominantly use the following methods to quantify EUC device emissions [13]:

- EUC device use phase GHG values are generated by converting no-user present energy consumption benchmark figures published online to CO_2e emissions units
- EUC device use phase GHG values are extracted from manufacturer carbon footprint reports
- EUC device use phase GHG values are created by software that calculates an average for each type of device
- EUC device use phase GHG values are created by a spreadsheet that calculates an average for each device type

Whereby accuracy is key when capturing EUC GHG emissions data, all four methods cause a range of inaccuracy as between 74-179% [1].

As such, it is reasonable to suggest that all four methods do not meet the validity criteria set for both science based targets [12] and GHG accounting [14]. To summarise how the inaccuracy is generated the following sections highlight an example in each instance.

Inaccuracy Example 1 - No-user Present Energy Benchmark Method

As previously noted, the TPCL benchmark measures 'no-user present' power draw and electricity consumption associated with low power modes such as 'off', 'sleep' and 'idle'. 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 [2]. 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].

Considering research [1] determines that on average employees operate computers in the active mode for an average of 5.6 hours per day whilst in the workplace, then this phase cannot be excluded from GHG emissions calculations.

Referring to the example given in scenario 1 (see above), using the Energy Star TEC value, the legacy Windows notebook is indicated to consume 15.7 kWh of electricity per device each year [2]. Applied to both science based target forming and GHG accounting, for a 500 user company the resulting current use phase GHG emissions would be 1,667 $kgCO_2e$.

However, based upon a real world measured annual electricity consumption the quantity of electricity consumed annually in the workplace is accurately determined to be 27.38 kWh per device [2]. As such, the actual target and accounting figure is 2,906 CO_2e GHG emissions.

Consequently, using the no-user present benchmark methodology to create science based targets or conduct scope 2 GHG accounting produces an inaccuracy of 74%.

Inaccuracy Example 2 - Manufacturer Carbon Footprint Report Method

EUC device manufacturers predominantly rely upon the non-user present energy efficiency benchmark to populate carbon footprint reports [1]. Consequently, relying upon such reports to quantify the emissions related to the device use phase carries forward the same level of error attributed to the 'No-user Present Energy Benchmark Method'. As such, the it is reasonable to state that organisations relying upon carbon footprint reports to form science based targets or undertake GHG scope 2 accounting will be subject to the same error.

However, to compound the issue there is a further complication included within such reports that causes incremental inaccuracy. Unless a specific location is declared within each report, the electricity conversion factor used to generate the CO_2e value will most likely not match the country where the device will be used.

As previously described, CO_2e GHG emissions are calculated by multiplying the electricity consumed value (kWh) by the GHG conversion factor published annually by each government where the energy is consumed. The factor is created to reflect the carbon intensity of the electricity supply grid.

EUC device manufacturers supply goods into regions with three different volts alternating current (V ac) electricity supplies including North America and Taiwan (115 V ac), Europe, Australia and New Zealand (230 V ac) and Japan (100 V ac). As the 115 and 230 V ac are the largest, the relevant product carbon footprint reports are predominantly produced for one or the other depending on the brand [1]. Whereas in limited cases, a global average is determined [1].

The reality is that each country within a region will have a different conversion factor based upon the carbon intensity included within the national supply grid. The factors differ because all countries adopt renewable energy at different rates. Therefore, a country with a higher percentage of renewable energy supply will have a lower conversion value as it is producing less emissions per energy unit consumed.

As an example the USA, which has been slow to transition to solar, wind and water source energy, has a conversion factor of 0.45322 compared to the UK factor of 0.21233. The difference being that for 10 kWh of electricity consumed in the former will create 4.5 $kgCO_2e$ compared to the latter of 2.1 $kgCO_2e$.

Returning to the previously described notebook highlights how this affects the accuracy of forming science based targets and undertaking scope 2 GHG accounting.

Referring to the example given in scenario 1 (see above), using the Energy Star TEC value, the legacy Windows notebook is indicated to consume 15.7 kWh of electricity per device each year [2]. Applied to both science based target forming and GHG accounting, for a 500 user company the resulting current use phase GHG emissions would be 1,667 $kgCO_2e$.

However, this same figure will be represented in a carbon footprint report using the North America region as 3,557 $kgCO_2e$ due to the non-country specific conversion factor. The result is consequently twofold. Firstly, it is 113% higher than the same value quantified by using the no-user present benchmark method. Secondly, it is 22% higher than the actual measured scope 2 emissions [2].

Consequently, setting aside the 74% error carried forward, two devices with an identical no-user present TEC value can differ by as much as 113% in miscalculated GHG emissions, simply by appearing in either a European or Americas focused carbon footprint report.

Inaccuracy Example 3 - Software and Spreadsheet Method

Both software and spreadsheet methodologies suffer from the issue of non-specificity that can introduce inaccuracies as high as 179% [1]. This is caused by the methods using measured use phase values from EUC device types (e.g. notebooks) rather than the specific notebook used by an organisation. As already highlighted in scenario 1, this approach is arguably inappropriate as EUC device energy efficiencies range considerably between device models even within the same category.

Using the Acer 513 Spin Chromebook and a popular estimation tool [1] as an example, the level of error introduced by the software and spreadsheet methodology is considerable.

The Acer 513 Spin Chromebook annual electricity consumption in the workplace is 10.74 kWh per device. As such, an organisation with 500 users will consume 5,370 kWh. Consequently, the concomitant annual scope 2 emissions for the EUC environment is 1,140 kgCO_2e.

Conducting the same calculation using the estimation tool, the Acer device is categorised as a notebook and an average electricity consumed value of 30 kWh is applied before translating this to scope 2 GHG emissions of 6.37 kgCO_2e per device.

The result for an environment of 500 users is 3,185 CO_2e.

As such, using the software or spreadsheet methodology introduces science based target forming and scope 2 GHG accounting errors as high as 179%.

Science Based Targets and EUC Scope 2 GHG Accounting Conclusion

As demonstrated, using real world energy consumption data captured by the Px^3 DUPA process enables organisations to avoid inaccuracies ranging between 74 and 179%. Using such a methodology validated by PhD research [1], substantiated by field research [2] and certified for compliance by Carbon Footprint, organisations are enabled to produce accurate EUC GHG scope 2 emissions values that are both accurate and meaningful. Doing so enables science based targets to be formed and GHG accounting to be undertaken that meets the requirements of both government policy [12] and legislation [10] and creates a clear pathway to future abatement.

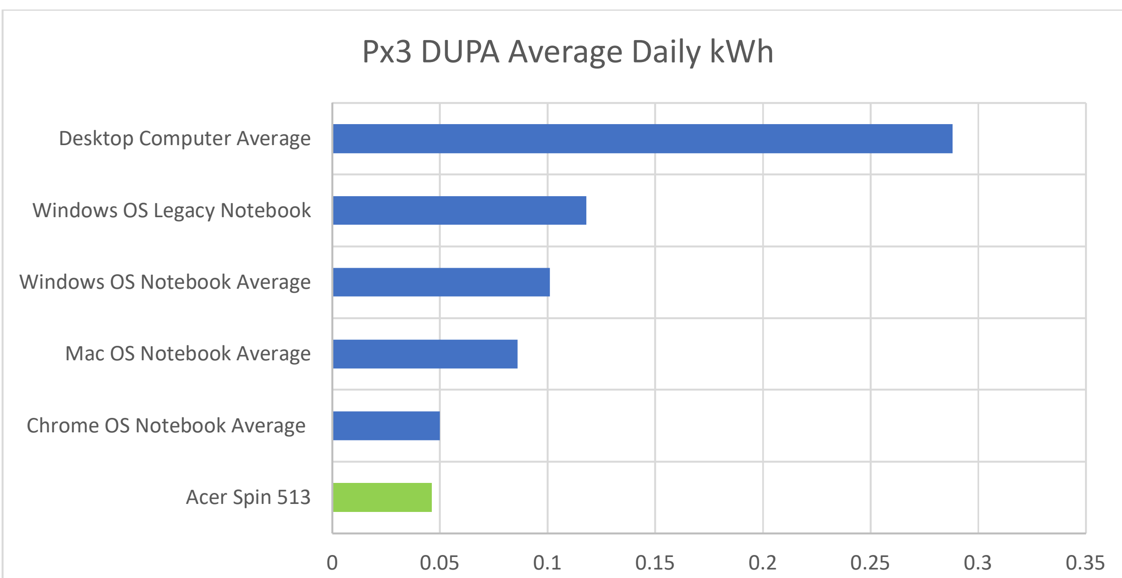
CSR and ESG Inclusion to Maximise Stakeholder Engagement

The Acer 513 Spin Chromebook is substantiated as being highly suitable for sustainability strategies focusing upon the abatement of GHG emissions by combining accurate device use phase analysis (DUPA) and comparison to similar devices.

Specifically, as previously examined, the Acer Spin 513 Chromebook consumes on average just 0.046 kWh of electricity during a structured working day. In context with devices of the same notebook classification and an average desktop computer (including a display), the Acer Spin 513 is:

- 8% more energy efficient during the use phase than the average equivalent Chrome OS notebook
- 47% more energy efficient during the use phase than the average equivalent Mac OS notebook
- 55% more energy efficient during the use phase than the average equivalent Windows 10 notebook
- 61% more energy efficient during the use phase than the average legacy Windows 10 notebook
- 84% more energy efficient during the use phase than the average legacy Windows 10 desktop computer and display

Figure 6 – DUPA average EUC device comparison for notebooks (source: Px[3] DUPA Technical White Paper)



Consequently, the positive environmental impact associated with the Acer Spin 513 Chromebook in relation to scope 2 GHG emissions ranges from 8% annual 84% abatement depending on the asset profile of an organisation's EUC environment.

Accurately measuring an organisation's EUC scope 2 GHG emissions is integral to setting a baseline and achieving future abatement. However, unless support for such an action resonates with all internal stakeholder groups, the activity may be short lived. As an example, research determines that the perceived impact of IT to tackle climate change diminishes among employees that are not involved with corporate and social responsibility (CSR) and environmental, social and governance (ESG) policy setting or subject to sustainability key performance indicators (KPI) [8].

Consequently, widening the appeal of IT sustainability strategies beyond management goals and key performance indicators to a personal 'IT user' level is essential to longevity and success [1, 8, 15]. To achieve this, ensuring that goals and success are communicated in a manner that can be both easily understood and appeal to personal interests, needs and viewpoints is important if sustainability focused behavioural changes are to be experienced across the whole organisation [1, 15].

Two effective strategies 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 following scenario acts as a summary of the information positioned previously by this research in relation to transitioning to a low energy EUC device. By doing so, it offers an example of potential content designed for a CSR or ESG annual report that includes a specific focus upon reducing scope 2 GHG emissions due to government policy [12] and legislation [10]. In each section, stakeholder interest is noted to determine which groups are most likely to be attracted by the results beyond the sustainability and CSR/ESG teams producing the information.

Scenario 4 – Simplifying and Personalising the Positive Environmental Impact of EUC GHG Abatement

Organisation XYZ has 500 computer users. Previously these users were supported by an EUC estate consisting of 20% desktop computers and 80% notebook computers. The desktops were accompanied by one LCD monitor and jointly consumed 66.92 kWh of electricity per year. The notebooks were more energy efficient and consumed 27.38kWh annually in the workplace.

Recently, all current EUC devices reached a five-year retention period and were replaced with an Acer 513 Spin Chromebook following energy efficiency substantiation tests. The transition supports key sustainability criteria including the formation of science based targets [12] and accurate GHG reporting [10] capable of reducing estates scope 2 and transportation scope 3 emissions. In turn, abatements in both areas substantiate commitment and ability to succeed in relation to the company CSR and ESG policies designed to address the updated government ICT sustainability policy [12] and climate change legislations [10, 18].

Electricity Consumption Reduction (CEO, CFO, COO and IT management)

Prior year EUC device annual electricity consumption was measured as 17,644 kWh. The associated annual utility operational cost was £2,470.

This year, EUC device annual electricity consumption reduced by almost 70% to 5,370 kWh. The associated annual utility operational cost is £752 saving £1,718.

Consequently, during the 5-year useful lifespan of the new low energy device a total utility cost saving of £8,590 will be realised.

Scope 2 GHG Emissions Abatement (CEO, CFO, COO, IT management, Human Resources, Employees)
As a result of the electricity consumption, prior year EUC device annual scope 2 GHG emissions was measured as 3,746 kgCO_2e.

This is equivalent to the pollution generated by driving 13,374 miles in an average fossil fuel propelled car. Such emissions require 4.5 acres of mature forest to sequester the resulting CO_2 from the atmosphere by the process of photosynthesis.

This year, EUC device annual scope 2 GHG emissions reduced by almost 70% to 1,140 kgCO_2e significantly exceeding the 30% abatement suggested by government policy [12].

The sustainable transition has delivered a scope 2 GHG emissions abatement of 2,606 kgCO_2e meaning that the equivalent pollution created by 9,443 car miles has been prevented this year. Consequently, over 3.1 acres of mature forest has been relieved from sequestering the avoided pollution.

Scope 3 GHG Emissions Abatement (CEO, CFO, COO, IT management, Human Resources, Employees)
Due to the legacy estate including 100 desktop computers, 20% of the workforce was required to work from the office 5 days per week.

Further to the transition to mobile computing not only has energy consumption and concomitant GHG emissions declined, so too has employee commuting.

As such, the new mobile environment has enabled the one hundred desktop computer users to operate from home for 40% of the working week. This means that 9,280 commuting days have been avoided during the last year.

Consequently, 68,672 kgCO_2e of scope 3 GHG emissions have been abated annually meaning that 82 acres of mature forest are no longer required to sequester the commuting to access IT (CAIT) related pollution.

Per Capita EUC Scope 2 GHG Emissions Reduction (CEO, IT management, Human Resources, Employees)
Previously, the average EUC device energy consumption per employee was 35.3 kWh resulting in individual annual scope 2 GHG emissions of 7.49 kgCO_2e.

As a result, the per capita Px^3 EVE ratio was 1:27 meaning that for every staff member the equivalent pollution caused by driving 27 miles was being emitted into the atmosphere annually.

This year the average EUC device energy consumption per employee was 10.74 kWh due to the adoption of the low energy Acer Spin 513 Chromebook, resulting in individual annual scope 2 GHG emissions of 2.28 kgCO_2e.

As a result, the per capita Px^3 EVE ratio has improved by almost 70% to 1:8 meaning that for every staff member the equivalent pollution caused by driving just 8 miles is now being emitted into the atmosphere annually.

Scenario 4 Conclusion
It is clear that in a business environment, the Acer Spin 513 Chromebook is the correct choice to support sustainable device procurement to support CSR and ESG strategies. Positioning the positive environmental impact in tangible and personal ways assists with stakeholder resonance. Board members and management tasked with strategy forming, results attainment and compliance will focus upon cost savings and environmental gains [1, 8]. Whilst human resources and employees, being the largest stakeholder group, can engagement via the personalised medium of the EVE ratio in the knowledge that sustainable device choice drives climate action [1, 2, 15].

Summary

As both legislation [10, 18] and policy [12] tighten causing a greater number of organisations to be subject to mandatory GHG emissions reporting and abatement [18], all sources of work related anthropogenic interference will be examined in the race to achieve net zero.

The 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 [7].

Producing 1% of global GHG annual emissions [1] with as much 50% attributed to use [1] behavioural changes related to the selection and operation of EUC devices 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.

This research offers substantiation to the significant abatements that could be achieved by adopting low energy consumption EUC devices. Specifically, the incredibly energy efficient Acer 513 Spin Chromebook has the capability to reduce EUC scope 2 emissions by as much as 70% in the workplace.

At an organisational level the opportunity is significant, abating 2,606 $kgCO_2e$ per 500 users for every year of the device's useful lifespan. At a national level, the impact is arguably far greater.

Research determines that 67% of workers require an EUC device to fulfil their job role [2] equating to 21.7m devices being used daily. Extrapolating the results generated by this research an estimated annual EUC use phase emissions value is in the region of 162,592,000 $kgCO_2e$. Consequently, by adopting low energy devices such as the Acer 513 Spin Chromebook this could be reduced to 49,494,240 $kgCO_2e$.

Doing so would prevent the equivalent pollution created by almost 410m car miles being driven and release almost 135,000 acres of mature forest from sequestering the way we work today.

Conclusion

As such, examining the evidence and examples documented by this research, organisations seeking to reduce scope 2 emissions ought to be compelled by the Acer 513 Chromebook. Exhibiting category leading energy performance in the field, the device consumes as little as 0.046 kWh per working day. This is equivalent to the energy required to take just 791 human steps. In context, the device out performs comparable notebooks by as much as 61% and average desktop computers by 84%. Consequently, organisations seeking to adopt sustainable IT strategies are enabled to achieve abatement goals, reduce electricity consumption accurately substantiate success by transitioning to the Acer 513 Spin Chromebook.

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About Px³

Px³ 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 Px³ 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. Px³ 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 Px³ 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 Px³ 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 Px³'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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