Microsoft

Driving climate action with Windows

Px3®

Abstract

The objective of the research is to answer the question, "can modern work applications and endpoints abate end user computing greenhouse gas emissions and drive climate action?" The purpose is to determine if Microsoft Windows effectively supports the United Nations aspiration to leverage existing technologies to lower societal emissions.

This is achieved in two stages. Firstly, by conducting an experiment to determine if endpoint cloud computing technologies influence notebook and desktop electricity consumption during the use-phase. Secondly, these findings together with further primary and secondary data are used to create greenhouse gas emissions pathways for two information technology strategies. These include operating endpoint devices on-premises and then as Windows 365 Cloud PCs.

The results determine that when applied to a 1,000-user group during the period 2023-2030, cloud computing-based approaches reduce scope 2 emissions by 4% as an average when compared to on-premises operations. Uniquely, Windows 365 Cloud PCs enable device useful lifespan extension and procurement displacement. This reduces scope 3 supply chain emissions by 55% for the period and 77% per capita ongoing. From a total carbon footprint perspective, end user computing greenhouse gas emissions are reduced by 46% for the period and 66% per capita ongoing.

Both utility and hardware procurement costs are also calculated to substantiate that sustainable information technology strategies support both planet and profit and therefore appeal to stakeholder role-based needs. The overall reduction to financial expenditure between the on-premises policy and the Windows 365 policy is 45% due to reduced utility and hardware procurement costs.

Bring your own PC schemes and remote working enabled by Windows 365 are also examined. In the case of the former, supply chain emissions were further reduced by 17% as dual-device ownership transitioned to single-device adoption. In the case of remote working, a reduction of annual commuting emissions of 20% per additional weekly remote working day adopted by all users.

It is concluded therefore that Windows-based modern work applications and endpoints are capable of driving significant climate action due to enabling the United Nations Sustainable Development Goal number 12, responsible production and consumption. As such, it is reasonable to state that end user computing using cloud technologies will contribute to the reduction of societal emissions if adopted at scale.

Keywords: Human-computer interaction; computer energy efficiency; computer product carbon footprint; scope 2 and scope 3 end user computing greenhouse gas emissions; sustainable information technology.

Chapter 1: Introduction

In 2017, it was recognised that human activity (anthropogenic interference) had caused 1.0°C of global warming [1] due to unnatural and unsustainable increases in greenhouse gas (GHG) emissions. A further temperature increase to 1.5°C above the normal will be reached by 2033, rising to 2°C by 2060. This is predicted with high certainty unless net zero global carbon dioxide (CO_2) emissions are achieved by mid-century, causing global warming to halt on a multi-decadal scale [1].

Net zero will only be achieved if the amount of GHG produced by human activity can be negated by reducing emissions generation and implementing methods of absorbing CO_2 from the atmosphere.

With a decade to meaningfully act, it is reasonable to suggest that the world cannot wait for strategic low-carbon initiatives, such as vehicle electrification and renewable energy transition, to mature. This is because sufficient diffusion and adoption will occur by mid-century at the earliest, causing 2°C to become inevitable. As an example, global electricity production from renewable energy sources is forecast to reach between 35-42% by 2030 [2]. While globally, the majority of countries taking climate action will not cease manufacturing and sale of fossil fuel vehicles until 2030.

To bridge the projected 32 Gigatonnes of Carbon Dioxide equivalent ($GtCO_2e$) emissions gap preventing sufficient abatement to achieve net zero and maintain 1.5°C warming, the United Nations Environment Programme and International Panel on Climate Change determine that, the world must combine existing technology with innovation to drive behavioural changes capable of reducing societal emissions [3].

Considering the criterion, a body of research proposes end user computing as a candidate technology for participation in this alternate strategy [4-12]. This is because, generating 1% of annual global GHG emissions [11] caused by the manufacture of 460m new devices each year and the electricity consumption of 4.2bn users [10, 11], this existing technology is a rich source of abatement and behavioural change.

The research substantiates that the key to achieving abatement via end user computing is related to the way we select and use personal computers. The concept aligns with the United Nations Sustainable Development Goals (SDG) formed in 2015 [13]. Consisting of seventeen goals, each has a specific focus that contributes to the creation of a sustainable future. Planned to mature in 2030, the goals include focus areas that, in context, apply directly to end user computing and GHG emissions reduction.

As an example, goal 12 is dedicated to responsible consumption and production. While production is governed by increasingly strict manufacturing legislation, raw material and energy efficiency monitoring and certification and recycling regulations [8], the management of consumption must be addressed by proposed behavioural changes. These include identifying and procuring devices with a low carbon footprint; keeping devices for longer periods of time to slow demand; using devices in the most energy-efficient manner during the use phase [7].

Achieving these three simple objectives is proven to drive goal number 13, climate action [7, 10, 12]. This is made possible by direct positive environmental impacts such as significantly reducing scope 2 electricity consumed emissions and scope 3 supply chain emissions. Additionally, where appropriate, indirect capabilities such as reduced scope 3 employee commuting emission are also experienced due to information technology (IT) enabled remote working solutions [6].

The key to ensuring maximum success is by delivering the ability to achieve all three strategies based upon the way end user computing is consumed. Windows and Windows 365 are capable of delivering such outcomes. As an example, the latest Windows operating system has a carbon-aware Windows Update function. For internet-connected devices, regional carbon intensity data is used to ensure updates only occur when low carbon energy supply is at its highest capacity within electricity grids. Additionally, changes have been made to default screen and sleep power settings to reduce scope 2 emissions generated in the idle mode.

While Windows 365 addresses energy consumption by transitioning end user computing workloads away from the end-point device into highly efficient cloud data centres powered predominantly by renewable energy [14]. As such, this enables sustainable IT strategies to be adopted without barriers. As an example, low-carbon-footprint devices, such as thin clients and tablets can be purchased without complexities such as required computing performance dictating device specification or type selection [12]. Also, devices can be kept for longer periods of time as performance obsolescence is avoided due to cloud PCs and applications being accessed via secure browser technologies [9]. Additionally, as the desktop instances are hosted with the secure cloud environments, then remote working becomes a possibility for all staff where appropriate [6].

To substantiate that Microsoft Windows technologies are capable of supporting responsible consumption and driving climate action, this research answers the question:

'Can modern work applications and endpoints abate end user computing greenhouse gas emissions?'

Chapter 2: Methodology

The research has three stages. The first is an experiment to determine if electricity efficiency is improved by using Windows 365. The second, applies the findings together with additional primary and secondary data to substantiate GHG abatement achieved by adopting a cloud PC based strategy. The third expands the discussion to examine additional sustainability options such as increased remote working and bring your own personal computer schemes enabled by the Windows 365 solution.

The experiment is designed to generate workplace electricity consumption data for three device types, including a desktop computer, notebook and tablet. The devices selected for measurement meet three key criteria. Firstly, they represent device types and models commonly used within a business environment [8, 15]. Secondly, product carbon footprint reports exist to enable scope 3 calculations [16, 17]. Thirdly, each device model is required to have been in production for at least two years to represent both legacy devices ready for replacement and potential new purchases.

Device energy measurement occurs twice. The first test uses the device with the operating system and productivity applications accessed locally. This approach is called 'on-premises'. The second utilises the device as a browser only interface to access both Windows 365 cloud PCs. Measurement of electricity consumption is conducted following the device use phase analysis (DUPA™) test set-up and conduct developed and used by the associated body of research [10]. Specifically, Energy Star low power state measurement parameters [18] are mirrored and expanded upon to include the active state power draw when the device is experiencing human-computer interaction. Doing so ensures accuracy by adhering to International Electrotechnical Commission standards [19, 20]. As such, instrumentation used is accurate to within 0.2%.

Each device is measured for power draw (Watts) and energy consumption (kilowatt-hours) when subjected to active state tasks. These include structured business productivity tasks (Active 1) and video conferencing (Active 2) operations to generate active-state energy data. The results are input into the commercial typical energy consumption (cTEC™) equation [10] to create an annual electricity consumption value (kWh/y).

The measurement results for each approach (on-premises and Windows 365) by device type are compared to determine if a percentage change in electricity consumption is apparent.

The second stage combines the electricity consumption results together with additional carbon footprint data [8], install-base statistics [8, 10] and influencing factors to create forecasted emissions pathways for an average group of 1,000 computer users following two differing IT policies.

These are:

- On-Premises Policy: This represents the 'no change' policy. The organisation with 1,000 users continues with local operating system devices and productivity applications. Devices continue to be refreshed in 5-year procurement cycles replacing 20% of the end user computing estate. Replacement devices are like-for-like with average carbon footprint devices selected.

- Windows 365 Policy: The policy adopts Windows 365 for all 1,000 users accessing both desktop and applications via cloud PCs. Device useful life span is consequently increased by 3 years to 8 years. Devices are therefore refreshed in 8-year procurement cycles, again replacing 20% of the end user computing estate during each phase. Replacement devices are selected based upon having the lowest carbon footprint [8].

In order to apply these findings to 1,000 users, the percentage of device types existing within a common business end user computing environment are determined. This is undertaken because differing device types create varying energy consumption values and therefore must be considered, if accurate representation is to be achieved. Associated research conducts asset profiling of over 2.3m end user devices currently in the workplace [8, 10]. As such, the findings create a substantive and unbiased data set outlining common mixes of computer types within large businesses.

The results from the measurement stage are used to create electricity consumption values for desktops, notebooks and tablets in the second stage. The body of research used to quantify proportionate representation also generates expansive average energy consumption values by type [10]. As such, average kWh values are used as a baseline with necessary percentage adjustments applied for each approach for the GHG pathways stage and based upon the experiment results. This is with the exception of monitors and thin clients as both will remain unaffected by the transitions [7]. This is because monitors will continue the exact same function regardless of policy, whilst the thin client devices are already utilising cloud computing based virtual desktop instances [7, 12].

The GHG emissions pathway time horizon is 2023 to 2030; the latter date being when the UN SDGs are anticipated to be achieved [13] and marginally ahead of the realisation of 1.5°C global warming in 2033 [1]. Computer product derived emissions are generated by two sources. The predominant being scope 3 supply chain emissions responsible for on average 73% of an end user computing device’s carbon footprint [8] and created by raw material acquisition, manufacturing, assembly, distribution and end-of-life processes. The second source being scope 2 use-phase emissions generated by electricity consumed during the device's useful life span [5, 8, 9].

To calculate the scope 3 supply chain GHG emissions included in the pathways, average values by computer type are derived from an application called the 'Dynamic Carbon Footprint™' [8, 10, 15] application. Developed during PhD research with the University of Warwick computer science faculty, the application database includes all available product carbon footprint data for end user computing devices for brands such as Acer, Apple, Asus, Dell, Lenovo, Microsoft and Phillips. A specific supply chain scope 3 emissions value is derived for the Microsoft Surface device [16] used to illustrate a transition to low carbon footprint devices for the Windows 365 policy.

Unlike scope 3 GHG emissions that are fixed by processes determined by the brand, such as manufacturing and distribution [8], scope 2 values will vary due to external factors including location of use and the year of use. This is because national electricity supplies exhibit different levels of carbon intensity within each country's electricity supply grid. In the context of this research, carbon intensity will decline during the pathway time horizon. As previously noted, the world is transitioning from a reliance on carbon intensive fossil fuel sources such as coal, gas and oil to generate electricity, to low carbon renewable energy sources such as hydroelectric, solar and wind.

Because of this influence, the pathways for each policy include emissions examples for three key regions. These are Europe, the United States (US) and a worldwide value called 'global'. To ensure the forecasted scope 2 calculations consider the current carbon intensity and planned renewable energy adoption plans for each region existing secondary data is used.

Scope 2 emissions are created by multiplying kWh/y (electricity consumed) data by electricity to GHG emissions conversion factors. The factor reflects kilograms of carbon dioxide released by the generation of each kWh of electricity. Factors are published annually by governments, further to requirements developed from the initial United Nations Framework Convention on Climate Change. Each factor is unique to the publishing country based upon the nation's electricity supply mechanism and infrastructure.

Values differ between nations as the proportional blend of fossil fuels used to generate combustion based electricity and contribution to the national grid from renewable energy adopted will change depending on available resources and government policy. To ensure the influence of device use in different locations is considered, three average factors are used for calculations.

For 2023, the global factor is determined by the average of carbon factors derived from fifty nations currently participating in GHG accounting and reporting [8]. Internationally, electricity production from renewable energy sources has reached 29% [2] and is forecast to reach between 35-42% by 2030 [2]. The increasing adoption is included within forecast calculations.

The European average factor value is derived from data published by thirty-three participating nations. Europe has currently achieved over 38% renewable electricity supply [10]. 63% diffusion is planned for 2030 [10] due to recasting of the Renewable Energy Directive 2018/2001/EU, the agreements within the European Green Deal and to meet aspirations presented by the REPowerEU report designed to alter supply networks following regional instability. Consequently, the carbon intensity factor declines accordingly and is included within calculations.

The US factor is based upon the country's current published value. To date, the US has achieved 21% renewable electricity supply mix [10]. While an executive order exists stating renewable energy will reach 100% by 2030, the US Energy Information Administration indicates a most likely outcome is 44%. As such, it is assumed that the carbon intensity factor will decline accordingly during the period based upon projected energy production sources. This reduction is also included within calculations.

Ensuring the use-phase scope 2 carbon intensity by location and computer type is appropriately considered is vital to emphasising the increasing importance of supply chain management as time progresses. This is because as electricity becomes lower in carbon intensity as time passes, the more dominant supply chain emissions become in relation to the product total carbon footprint.

In Europe, an average notebook used for 5-years will generate approximately 298 kilograms of carbon dioxide equivalent (kgCO_2e) of combined supply chain and use-phase GHG emissions. As such, the scope 2 emissions are responsible for 11% of the computer's total emissions during the useful lifespan. Examining the same scenario in 2030 indicates that the same device will theoretically generate 4% less total emissions at 286 kgCO_2e. This is because low carbon renewable energy adoption will have increased by this time causing the scope 2 emissions to contribute to 7% of the total carbon footprint. In this example, it is clear that the scope 2 contribution has declined by 37% during the period. As such, while electricity consumption and device efficiency will remain a focus throughout the time horizon from a financial cost perspective, the importance from an environmental impact perspective diminishes as renewable energy adoption increases.

Consequently, end user computing policies that support extended device life spans and procurement of computers with a low supply chain carbon footprint will become increasingly important to drive climate action during the coming decade [10, 12].

When the conversion factor is multiplied by the electricity consumption value (kWh), a GHG gas emissions unit measured in kilograms of carbon dioxide equivalent (kgCO_2e) is generated as per international GHG emissions accounting protocol. Together with the same unit generated by scope 3 supply chain LCA calculations, $kgCO_2e$ values are used to populate the 1,000 user emissions pathway examples.

As noted, for each pathway, use-phase electricity consumption emissions and newly generated supply chain emissions are quantified based upon two defined policies. The reason is to indicate the short and long-term environmental impact associated with each combination of computer use and procurement behaviours. As such, annual and cumulative values are generated to highlight which policy may prove the most effective from a sustainability perspective. While emissions values are indicated in $kgCO_2e$ as noted, equivalent tangible values are also included where applicable to increase immediate comprehension of pollution generated or avoided.

The values include forest acres required to remove (sequester) the carbon produced by end computing practices from the atmosphere by the natural process of photosynthesis. Plus, the number of miles driven by a combustion engine car to produce the equivalent GHG emissions caused by each policy.

Research also determines that barriers to the diffusion of sustainable end user computing strategies exist within business management stakeholders [4]. This is predominantly based upon an incorrect perception that information technology that is good for the planet is not good for profit [4]. To ensure that proof to the contrary is apparent, any utility and procurement cost savings are outlined within the results.

For simplicity of comparison between policies, utility costs are compared using a global cost per kWh and defined in US$. As before it is recognised that this value will increase during the pathway time horizon. In order to generate a current and ongoing cost per unit of electricity secondary IEA median data is used. While uncertainty exists in relation to future electricity costs, data for the preceding 8-year period from 2014-2021 indicates a 31% rise in supply prices. As such this applied to the current cost of 1 unit (kWh) of commercial electricity from 2022-2030 using a compound annual growth ratio.

In relation to device procurement costs it is recognised that costs associated with computers are highly variable even within the same type. As an example, one desktop computer can cost $500 while another similar variant can cost $1,000. As such, the following assumptions are made for computer hardware replacement costs. Assessing popular computer brand websites average prices are determined by device type. As highlighted in figure 6, the average current cost for a desktop computer is $700, a thin client desktop $450, a notebook $850, a tablet $750 and a standard monitor $250.

The cost values are used to demonstrate feasible savings achieved by two sustainability strategies. The first is displacement opportunity delivered by device useful life span extension that cause procurement cycles to shift from every 5-years to 8-years. The second is delivered by an opportunity to procure alternative less expensive devices such as thin clients in place of desktops enabled by transitioning to Windows 365.

The third and final stage of the research examines two associated abatement opportunities enabled by Windows 365. These include reducing scope 3 supply chain values further by introducing bring your own PC (BYOPC) schemes. Plus, encouraging remote working to reduce employee commuting GHG emissions. The two approaches are not included within the initial pathway examples as the potential reductions are based upon assumed levels of adoption. As such, including the data within the pathways would cause the two policies to be incomparable having strayed beyond the defined parameters of product focused GHG emissions and abatement.

To determine feasible BYOPC abatement impact it is assumed that the 1,000 user company has adopted the Windows 365 policy. This is based upon the fact that doing so enables secure desktop access from any device. As before, devices are refreshed in 8-year procurement cycles again replacing 20% of the end user computing estate. Whilst desktop style computers continue to be purchased by the organisation, unlike the Windows 365 policy, new company owned replacement mobile devices (notebooks and tablets) are not purchased and the scope 3 value is realised as zero. This is based on the assumption that employees will already own or intend to purchase a personal device and as such total displacement of secondary business mobile devices is achieved.

While the BYOPC policy begins in 2026 as devices meet the end of the 8-year retention policy, desktop and thin client devices follow the same pattern as the previous Windows 365 strategy based upon the devices being used for desk based roles. The difference in this instance is that the notebook replacement begins to mirror global personal preference statistics [10] rather than a wholesale transition to tablets. This is based upon the rationale that employees will begin to use their usual choice of device for the BYOPC work policy. Based upon statistics, 40% of users purchasing mobile devices will select tablets whilst 60% will choose notebooks.

To determine feasible remote working abatement impact it is assumed that the 1,000 user company has adopted the Windows 365 policy. This is based upon the fact that doing so enables secure desktop access from any device from any location. To highlight quantities of scope 3 commuting GHG emissions that could be avoided by increasing numbers of days working from a location other than the office, four comparative values are generated. These include no remote working days to create a baseline; 1 day of remote working per week; two days and finally three days. The data used to generate the scope 3 emissions values are determined by associated research conducted in the field of abating transport emissions via remote working enabled by IT solutions. Specifically, further to a two-year examination of the commuting habits of over 800 employees working in twenty-four countries [6], it is determined that with no remote working ability available, a single user creates 2,096 kgCO_2e of commuting emissions.

Chapter 3: Results

The results section examines the findings of the electricity consumption measurement experiment before determining the GHG emissions pathways created by two policies using on-premises and Windows 365 end user computing strategies.

3.1 Electricity consumption measurement experiment

The initial experiment is conducted to determine if on-premises device electricity consumption is influenced by adopting Windows 365. The hypothesis being that as computer processing transitions from an on-premises end-point computing device to a cloud data centre, then it is reasonable to suggest reductions in component power draw may be experienced. If the kWh results decline by doing so, then concomitant scope 2 GHG emissions too will decline, therefore influencing the pathway forecasts calculated in the second stage.

The three devices measured include a Lenovo ThinkPad T14 Generation 2 notebook, a Lenovo ThinkCentre M90 small form factor desktop computer and a Microsoft Surface Pro X 2-in-1 tablet. All three computers are installed with Microsoft Windows operating systems and represent popular devices used within the workplace [8, 10]. A HP M27 monitor, USB keyboard and mouse are also used in conjunction with the desktop and measured for electricity consumption to ensure the power draw is constant as anticipated.

3.1.1 Desktop computer energy performance

The desktop computer hardware specification is considered as standard for the device type. Specifically, the small form factor device includes a 10th Generation Intel® Core™ i5-10600 vPro central processing unit (CPU), 8GB of double data rate fourth generation (DDR4) memory and 256GB solid-state drive (SSD) for local storage.

Measured when operated using the standard on-premises approach utilising the local operating system and applications, the Lenovo desktop computer active state average power draw was 17.66W and 0.01766 kW when subjected to human-computer interaction. This represents a 40% increase in power draw increase when compared to the short idle mode measurement of 12.6W. The increase from the short idle to active state is anticipated and congruent with associated research [5, 9, 10] determining that all devices will experience raised power draw during human-computer interaction due to additional processing not experienced during the low power modes such as off, sleep and idle.

Extrapolated to one year using the commercial typical energy consumption (cTEC™) methodology [10], it is determined that the device consumes 29.84 kWh/y in the on-premises state (figure 1). For contextual purposes the device consumes the equivalent energy required to take 2,212 steps during each working day.

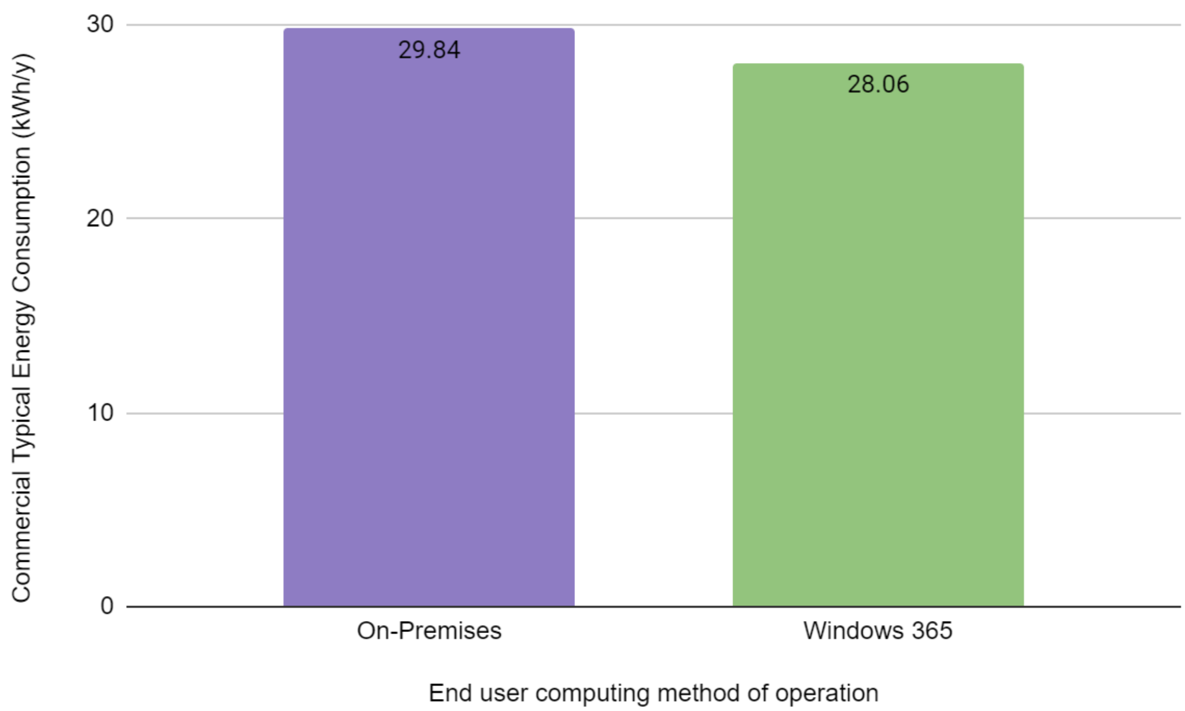
As such, when compared to the average desktop computer energy consumption values (see methodology), the device could be considered as highly energy efficient. In context, when examining smaller form factor devices, the energy consumption is close to the average, being 30 kWh [10].

Having determined the power baseline for the desktop computer, the test practice was repeated using the same device to access a Windows 365 cloud PC. In this example, the desktop computer's average active-state power draw was 15.95 W or 0.01595 kW. This represents a 27% increase in power increase when compared to the short idle mode. Extrapolated to one year, the cTEC™ value for electricity consumption in the workplace is 28.06 kWh/y (figure 1) equivalent to 2,084 steps during each working day.

Notably, the power draw peak was lowest in relation to the Windows 365 approach. As an example, the on-premises power draw rose to 70.9W at the highest point, whereas the Windows 365 peak device power draw rose to 54.3W.

As such, it is determined that Windows 365 approach to end user computing operation reduces desktop computer electricity consumption by 6% on average (figure 1).

Figure 1. Desktop computer electricity consumption (kWh) for on-premises and Windows 365 operations



It is noted that as anticipated, the HP M27fw 27” monitor remained consistent in relation to power draw and electricity consumption when subjected to on-premises and SaaS approaches. The results are congruent with prior research [5, 7, 9, 10, 12] and is caused by the display fulfilling the same function for all approaches. As such, the results are not relevant to the experiment stage.

3.1.2 Notebook computer energy performance

The notebook computer architecture is also common to the device type; in this instance including a 14" screen, Intel Core i5 11th generation CPU, 8GB DDR4 memory and 256GB SSD storage.

When measured during the active-state and operated using the on-premises approach, the average active state power draw was 13.92W or 0.01392 kW. In this example, the results represent a 132% increase from the short-idle mode measurement of 6W.

Extrapolated to one-year of electricity consumption, the cTEC™ value is 19.12 kWh/y (figure 2) and therefore similar to the notebook global average of 22.35 kWh/y (see methodology). The value is equivalent to the energy required to complete 1,418 walking steps during each working day.

As the notebook is capable of operating without a peripheral monitor it is worthwhile comparing the energy equivalent step count associated with the previously measured on-premises desktop when combined with an average monitor. In this example, the step total for the desktop solution is 5,622 or 4,204 more each working day than the notebook. When simplified in this way, it is effectively emphasised that mobile computing options such as notebooks, are considerably more energy efficient that desktop chassis devices due to the requirement of a dedicated peripheral display.

From an environmental perspective, as electricity consumption is responsible for indirect upstream scope 2 GHG emissions, it is reasonable to suggest that carbon footprint increases caused by device type selection must be questioned if overall abatement is to be achieved. Specifically, if a static device such as a desktop is not essential to a work role and could be fulfilled with a mobile device or similar more efficient option, then alternatives should be considered.

Measured when utilising the Windows 365 approach, the notebook active state power draw reduced by just over 16% to 11.63W or 0.01163 kW. This represents a 93% increase in power draw compared to the short idle mode. Extrapolated to one-year of electricity consumption, the cTEC™ value is 16.81 kWh/y (figure 2) and equivalent to 1,246 steps. In this instance the notebook becomes highly energy efficient, achieving 25% less consumption than the global notebook average (see methodology).

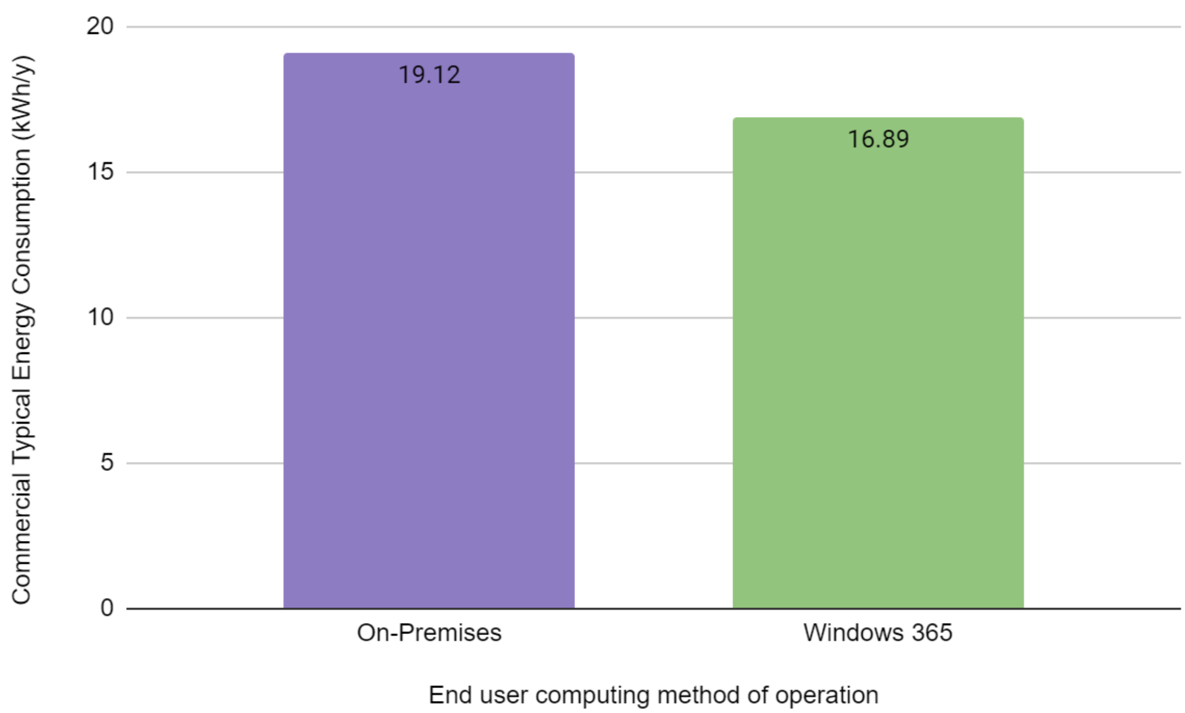
However, it is notable that while the energy consumption reduction values for both the desktop computer and notebook are similar, with only 0.56kWh/y in favour of the mobile device, the percentage impact is quite different.

Specifically, the substantiated desktop reduction per year is 6% whereas the notebook delivers double this at 12%. As such, it is reasonable to suggest that network traffic may be responsible for the disparity.

Considering that a standard wireless fidelity (Wi-Fi) network adapter will draw in the region of 2W and an Ethernet network interface card approximately 10W, then the indication is feasible. The rationale being that the desktop device utilised the latter and the notebook the former.

As such, computer hardware relying on wired network connectivity and producing constant data traffic will increase power consumption as is congruent with the findings. In summary, for notebook computers, it is determined that a transition from an on-premises approach to Windows 365 reduces electricity consumption by 12% (figure 2) when used in the workplace.

Figure 2. Notebook computer electricity consumption (kWh) for on-premises and Windows 365 operations



3.1.3 Tablet computer energy performance

The Microsoft Surface Pro X tablet is used in the context of the research to represent a low carbon footprint mobile computer alternative to devices that generate higher total emissions values, such as notebooks. This is particularly pertinent to the Windows 365 approach as the device acts as a browser portal used to access the cloud PC. This creates what is effectively a low environmental impact mobile thin-client.

As such, the tablet is used to enable calculation of the Windows 365 pathway example during a transition to low carbon footprint devices.

As anticipated and congruent with the average electricity consumption by device type data (see methodology) the tablet exhibits the greatest level of energy efficiency. Research highlights that such efficiency is aided by components that require less power draw when compared to standard components [9, 10]. In this example, the device includes a reduced thermal design power (TDP) central processing unit (Microsoft SQ1 @3.0 GHz ARM based) and 8GB low power double data rate memory plus a standard 256GB SSD drive.

Measured when subjected to human-computer interaction, the Microsoft Surface device power draw is 10.01W or 0.0101 kW. This represents a 245% increase in power draw when compared to the short idle mode measurement of 2.9W.

Extrapolated to one year, the tablet's cTEC value is 13.8 kWh/y. This electricity consumption metric will be used together with the scope 3 data (see below) to generate the Windows 365 GHG pathway in stage 2 of the results.

The electricity used is equivalent to 1,020 human steps, again emphasising the environmental value of such devices when compared to the desktop and monitor combination that required 450% more equivalent activity.

3.2 End user computing GHG emissions pathways by policy

As discussed, two policies are used to forecast GHG emissions pathways generated by use (electricity consumption) and new replacement product purchases (supply chain) during the time horizon 2023-2030. The policies include on-premises and Windows 365.

3.2.1 On-Premises Policy Results

The on-premises policy represents 'no change' being applied to current end user computing strategies. The organisation with 1,000 users continues with local operating system devices and locally processed productivity applications. Devices continue to be refreshed in 5-year procurement cycles replacing 20% of the end user computing estate. Replacement devices are like-for-like with average carbon footprint devices selected.

Table 1 highlights the electricity consumption values generated by this approach. As noted, the results remain constant as devices are replaced with the same type and similar specification. In this example, average annual energy use is 66,634 kWh/y, meaning that for every user 66.63 kWh/y is consumed. Cumulatively, for the on-premises policy 533,072 kWh of electricity is consumed during the forecast time horizon.

Table 1. End user computing electricity consumption (kWh) for the on-premises policy

Device Type	Portion install base (%)	Average kWh/y per unit	2023 (kWh)	2024 (kWh)	2025 (kWh)	2026 (kWh)	2027 (kWh)	2028 (kWh)	2029 (kWh)	2030 (kWh)
Desktops	32	48.33	15,466	15,466	15,466	15,466	15,466	15,466	15,466	15,466
Notebooks	58	22.35	12,963	12,963	12,963	12,963	12,963	12,963	12,963	12,963
Tablets	6	11.74	704	704	704	704	704	704	704	704
Thin clients	4	17.52	701	701	701	701	701	701	701	701
Monitors	80	46	36,800	36,800	36,800	36,800	36,800	36,800	36,800	36,800
Total		66.63	66,634	66,634	66,634	66,634	66,634	66,634	66,634	66,634

From a financial perspective, the increasing annual price per kWh determined in the methodology causes a 27% price increase by the end of the period. On average, annual utility costs are $8,564 (table 2). Cumulatively, the 1,000 user organisation will spend $68,513 on use-phase end user computing electricity consumption during the forecast period.

Table 2. End user computing utility costs (US$) for the on-premises policy

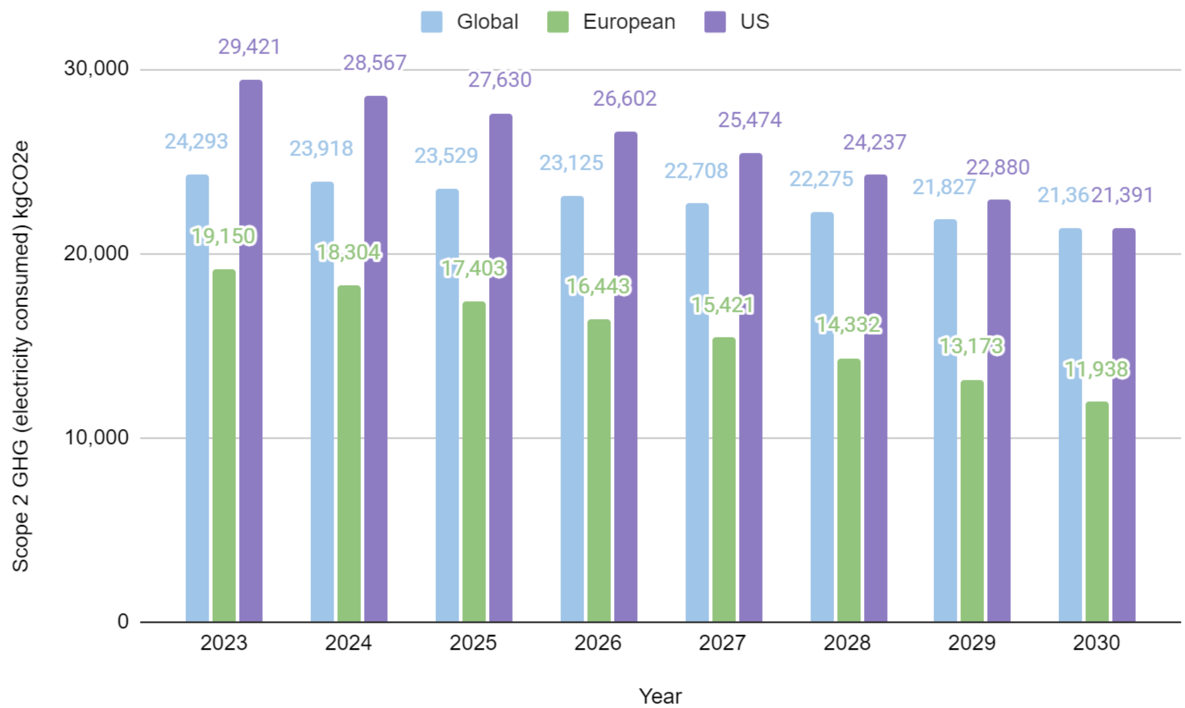
Device Type	2023 (US$)	2024 (US$)	2025 (US$)	2026 (US$)	2027 (US$)	2028 (US$)	2029 (US$)	2030 (US$)
Desktops	1,760	1,821	1,883	1,948	2,016	2,085	2,157	2,232
Notebooks	1,475	1,526	1,579	1,633	1,689	1,748	1,808	1,870
Tablets	80	83	86	89	92	95	98	102
Thin clients	80	82	85	88	91	94	98	101
Monitors	4,188	4,332	4,482	4,636	4,796	4,962	5,133	5,310
Total	7,583	7,844	8,115	8,395	8,684	8,984	9,294	9,615

Applying the annual electricity to GHG emissions factors determined in the methodology to the electricity consumption results, on-premises device energy consumption produces three values based upon the location of use. The lowest value is produced by computer use in Europe due to the previously noted high levels of current and planned low carbon renewable energy adoption in the region. Annual average scope 2 emissions are 15,771 $kgCO_2e$ decreasing from 19,150 $kgCO_2e$ in 2023 to 11,938 $kgCO_2e$ in 2030. This is equal to an annual average of 15.8 $kgCO_2e$ per user. Cumulatively, the policy creates 126,164 $kgCO_2e$ (figure 3). The GHG emissions are equivalent to the pollution produced by 460,000 combustion car miles and requires 19 forest acres each year to remove the resulting carbon from our atmosphere.

The mid impact value is produced by the global operations scenario. Annual average scope 2 emissions are 22,880 $kgCO_2e$ declining from 24,293 $kgCO_2e$ in 2023 to 21,363 in 2030. This is equal to generating 22.9 $kgCO_2e$ of emissions on average per user each year. The global use example cumulatively creates 183,037 $kgCO_2e$ (figure 3). Being 45% higher than the European value the environmental impact is equivalent to 666,400 car miles and requires 27 forest acres to sequester the carbon.

Due to the current carbon intensity of the national grid and forecasted plans for adopting renewable energy, the US location of use result produces the highest use-phase GHG emissions value. Annual average scope 2 emissions are 25,775 $kgCO_2e$ declining from 29,421 $kgCO_2e$ in 2023 to almost equivalent with the European value at 21,391 $kgCO_2e$ by 2030 due to accelerating adoption of low carbon energy sources. This is equal to 25.8 $kgCO_2e/y$ on average per user. Cumulatively, the policy creates 206,202 $kgCO_2e$ (figure 3) being 63% and 13% higher than the European and global values respectively. The value is equivalent to 750,917 car miles and requires 31 forest acres to remove the resulting carbon from the atmosphere.

Figure 3. End user computing scope 2 (electricity consumed) annual GHG emissions (kgCO_2e) for the on-premises policy by location of use



The on-premises policy creates new product scope 3 emissions from 2023 onwards based upon the unchanged 5-year retention strategy. The ongoing cycle causes 20% of devices to refresh each year as the replacement age is reached.

As such, 99,024 kgCO_2e of supply chain GHG emissions are generated each year due to new product procurement equivalent to 99 kgCO_2e per user per year (table 3). This requires 119 forest acres each year to sequester the resulting carbon from the atmosphere.

Cumulatively, the purchasing strategy creates 792,192 kgCO_2e during the forecast period. This is equivalent to the pollution caused by driving 2.9m miles in a combustion propelled car.

Calculating the global cumulative use-phase consumption (183,037 CO_2e) and supply emissions contribution to the 8-year total carbon footprint, it is determined that of the 975,229 kgCO_2e produced, 81% is attributed to the manufacture and distribution of devices.

When considered in context with the electricity consumption findings suggesting that device types play an integral role in relation to scope 2 GHG abatement, it is clear that the same conclusion can be drawn for the supply chain scope 3 abatement. As an example, the annual replacement of one desktop and monitor combination generates 545 kgCO_2e. In comparison, replacing a notebook causes 60% less scope 3 emissions and a tablet 80% less (table 3).

Table 3. On-premises end user computing scope 3 (supply chain) GHG emissions (kgCO_2e)

Device Type	Units per 1,000 users	Average Scope 3 GHG per unit (kgCO2e)	2023 New Product Scope 3 Emissions (kgCO2e)	2024 New Product Scope 3 Emissions (kgCO2e)	2025 New Product Scope 3 Emissions (kgCO2e)	2026 New Product Scope 3 Emissions (kgCO2e)	2027 New Product Scope 3 Emissions (kgCO2e)	2028 New Product Scope 3 Emissions (kgCO2e)	2029 New Product Scope 3 Emissions (kgCO2e)	2030 New Product Scope 3 Emissions (kgCO2e)	Cumulative New Product Scope 3 Emissions (kgCO2e)
Desktops	320	221	14,144	14,144	14,144	14,144	14,144	14,144	14,144	14,144	113,152
Notebooks	580	266	30,856	30,856	30,856	30,856	30,856	30,856	30,856	30,856	246,848
Tablets	60	110	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	10,560
Thin clients	40	108	864	864	864	864	864	864	864	864	6,912
Monitors	800	324	51,840	51,840	51,840	51,840	51,840	51,840	51,840	51,840	414,720
Total			99,024	99,024	99,024	99,024	99,024	99,024	99,024	99,024	792,192

As previously noted, to enable credible evidence to emphasise that sustainable IT strategies can also benefit the profit part of the triple bottom line, in addition to utility costs, most likely procurement expenditure must also be calculated.

Based upon the current 5-year replacement policy, 360 devices are replaced annually as 20% of the 1,000 computers and 800 monitors reach the end of their perceived useful lifespan. As highlighted in table 4, in the case of the unchanged on-premises approach, this procurement cycle generates an annual new computer spend of $196,000. Cumulatively, this equates to $1,568,000 between 2023 and 2030 (table 4) or $1,568 per user.

Table 4. On-Premises end user computing replacement cycles and procurement costs (US$)

Device Type	Units per 1,000 users	Annual Replace ment Units	2023 New Product Cost	2024 New Product Cost	2025 New Product Cost	2026 New Product Cost	2027 New Product Cost	2028 New Product Cost	2029 New Product Cost	2030 New Product Cost	Cumulative New Product Cost
Desktops	320	64	$44,800	$44,800	$44,800	$44,800	$44,800	$44,800	$44,800	$44,800	$358,400
Notebooks	580	116	$98,600	$98,600	$98,600	$98,600	$98,600	$98,600	$98,600	$98,600	$788,800
Tablets	60	12	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000	$72,000
Thin clients	40	8	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$28,800
Monitors	800	160	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000	$320,000
Total		360	$196,000	$196,000	$196,000	$196,000	$196,000	$196,000	$196,000	$196,000	$1,568,000

3.2.1.1 On-Premises policy pathway 2023-2030

The emissions calculations determine that scope 2 use-phase emissions for the period 2023-2030 are 183,037 kgCO_2e if an organisation is operating on a global basis; 126,164 kgCO_2e when operating in Europe and 206,202 kgCO_2e for the US.

Scope 3 supply chain values are not influenced by location and therefore are 792,192 kgCO_2e for all locations.

As such, figure 4 highlights that continuing with the on-premises policy in Europe, again produces the lowest overall environmental impact due to the influence of low carbon energy supply. Specifically, a total carbon footprint of 918,356 kgCO_2e GHG emissions is caused by end user computing operations undertaken by the 1,000 user group. In this example, use-phase emissions represent 14% of the total and therefore supply chain emissions 86%. The average annual total emissions are 114,795 kgCO_2e or 115 kgCO_2e per user per year.

The cumulative GHG emissions created by the European on-premises policy are equivalent to the pollution created by driving 3.34m car miles. Annually, the pollution requires just over 138 forest acres to remove the pollution from the atmosphere.

In comparison, an organisation operating in the US produces the highest environmental impact due to a slower adoption of renewable energy within the national supply grid. A total product focused carbon footprint of 998,394 kgCO_2e is generated during the emissions pathway, causing an impact of almost 1 ton of GHG emissions created by end user computing for each of the 1,000 employees. In this instance, the contribution of use-phase increases to 21% reducing the supply chain emissions to 79%. The average annual total emissions value is 9% higher than the European finding and equal to 124,799 kgCO_2e or 125 kgCO_2e per user per year.

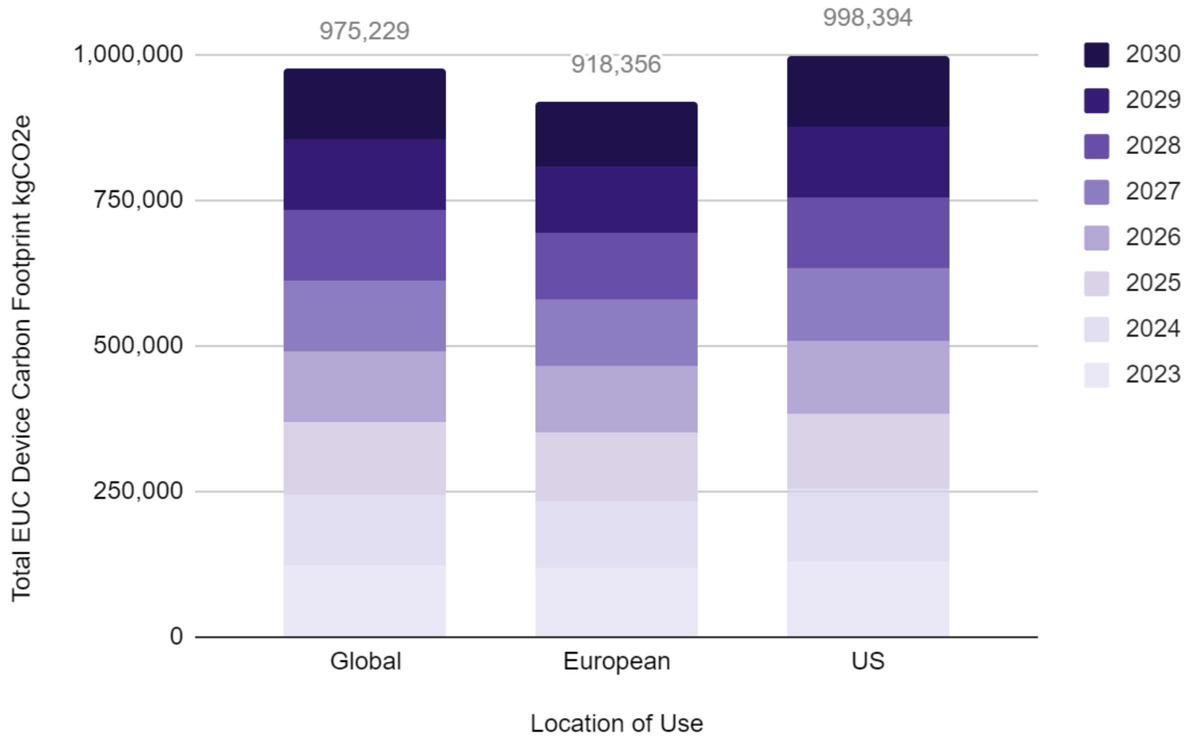
From an analogous perspective, the cumulative GHG emissions for the US operations are equivalent to the pollution created by driving 3.65m car miles, requiring 150 forest acres each year to sequester the pollution.

Finally, when assessed as a global average, on-premises style end user computing operations for 1,000 users generate a total of 975,229 kgCO_2e GHG emissions. The emissions are equivalent to pollution generated by 3.55m car miles and requires 146 forest acres to sequester the carbon. As anticipated, this represents a median for environmental impact, being 6% above the European value and 2% below the US value.

In this context, it becomes clear that when examined as a whole, while electricity consumption remains a key factor, it is embodied scope 3 emissions that offer the greatest opportunity to abate computing GHG emissions.

As an example, even though the US conversion factor is currently 18% higher than the global factor, the fact that both values become equivalent in 2030 causes scope 3 supply chain emissions to account for 81% of the total global carbon footprint.

Figure 4. On-Premises total end user computing device carbon footprint (kgCO_2e) by location



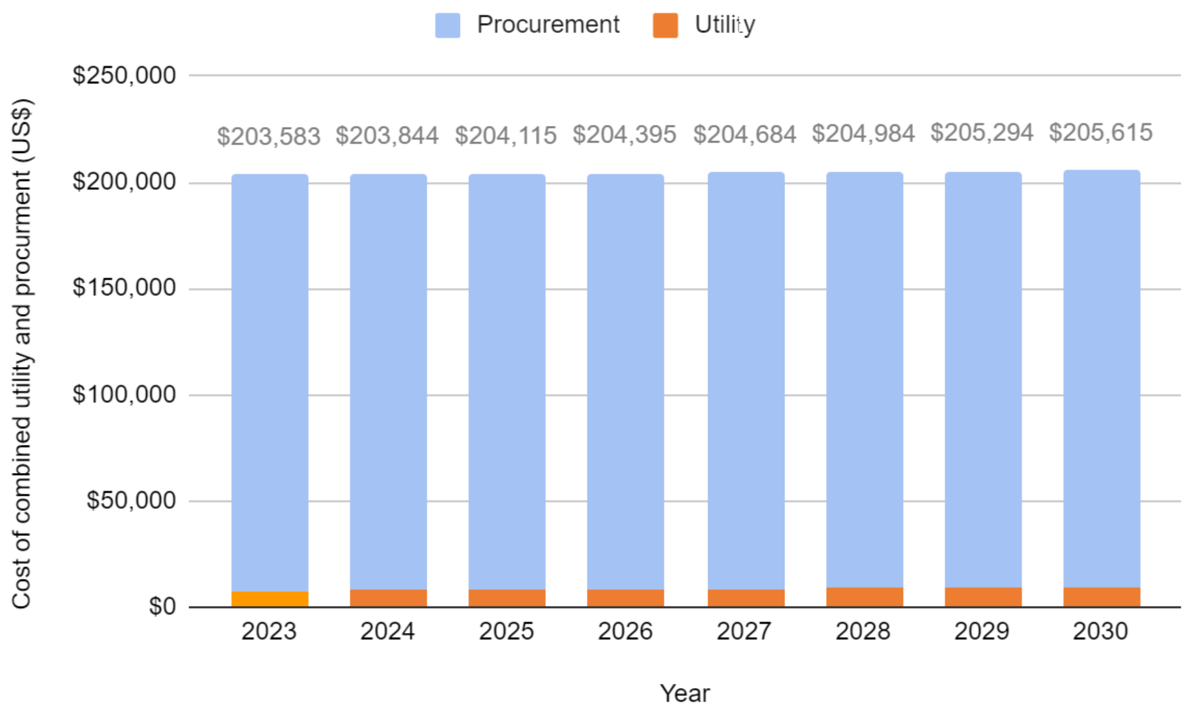
The dominance of new product based impacts also reflects within the profit metrics produced by the on-premises results. Replacing 20% of devices each year and setting the useful lifespan expectation to 5-years creates an annual recurring purchasing expenditure of $196,000 (table 4) compared to the utility average of $8,564 (table 2).

As previously noted, based upon no change to the existing end user computing policy, the global average cumulative electricity consumption cost is $ 68,513 (table 2) while total procurement costs are $1,568,000.

Consequently, the total combined operational and capital expenditure is $1,636,513 for the period when calculated as a global average with annual costs rising from $203,583 in 2023 to $205,615 in 2030.

Of this value, utility costs represent just 4% of the total with procurement consuming 96% of the available budget. The findings once again emphasise the necessity to focus upon device types and lifespan longevity if both planet and profit metrics are to be meaningfully reduced by sustainable IT strategies.

Figure 5. Total end user computing combined hardware and utility costs (US$) for the on-premises policy



3.2.2 Windows 365 Policy Results

The second policy adopts Windows 365 for all 1,000 users accessing both desktop and applications via cloud PCs. Device useful life span is consequently enabled to be increased by 3 years to 8 years, as hardware performance obsolescence, future application compatibility and operating system updates issues are avoided as devices effectively transform to browser based thin clients.

Unlike the on-premises policy, devices are therefore refreshed in 8-year procurement cycles, again replacing 20% of the end user computing estate during each phase. In this instance, new devices are selected based upon having the lowest carbon footprint and being suited to the required function. As noted, desktop computers transition to desktop chassis thin client computers and notebooks to Microsoft Surface 2-in-1 tablets.

From an electricity consumption perspective, it is both the device transformation and additional energy efficiency generated by the Windows 365 approach that reduces utility values. As highlighted by table 5, for the first three years (2023-2025 inclusive) before device replacement begins, electricity consumption is reduced by 4% overall.

From 2026 onwards desktops begin to be replaced with more energy efficient thin client computers and notebooks with the Microsoft Surface tablet style device. Incremental improvements in efficiency cause annual electricity consumption to decline to 55,963 kWh/y. At this point, the values are 16% lower than the on-premises results of 66,634 kWh/y. Consequently, while the on-premises approach generates a cumulative electricity consumption of 533,070 kWh/y, the Windows 365 based approach reduces utility values to 485,063 kWh/y.

In total, the Windows 365 solution, when used by 1,000 employees during the pathway period, requires 48,007 kWh/y less electricity than the on-premises solution saving 6,000 kWh per year.

Table 5. End user computing electricity consumption (kWh) for the Windows 365 policy

Device Type	Units per 1,000 users	Average kWh/y per unit	2023 kWh/y	2024 kWh/y	2025 kWh/y	2026 Units per 1,000 users	2026 kWh/y	2027 Units per 1,000 users	2027 kWh/y	2028 Units per 1,000 users	2028 kWh/y	2029 Units per 1,000 users	2029 kWh/y	2030 Units per 1,000 users	2030 kWh/y
Desktops	320	45.43	14,538	14,538	14,538	256	11,630	205	9,313	164	7,451	131	5,951	105	4,770
Notebooks	580	19.67	11,407	11,407	11,407	464	9,126	371	7,297	297	5,841	238	4,681	190	3,737
Tablets (existing)	60	11.74	704	704	704	48	564	38	446	30	352	24	282	19	223
Tablets (new)	0	13.84	0	0	0	128	1,772	231	3,197	313	4,332	378	5,232	431	5,965
Thin clients	40	17.52	701	701	701	104	1,822	155	2,716	196	3,434	229	4,012	255	4,468
Monitors	800	46	36,800	36,800	36,800	800	36,800	800	36,800	800	36,800	800	36,800	800	36,800
Total			64,150	64,150	64,150		61,713		59,769		58,210		56,958		55,963

The electricity consumption reduction influences the utility costs. As such, 4% reduction is experienced during the first three years as the device type remains unchanged due to the lifespan extension. However, the transition to energy efficient devices causes desktops to decline in quantity from 320 in 2023 to 105 in 2030 and thin clients to increase from 40 to 255. Similarly, notebooks decline from 580 per 1,000 users to 190 units, while the replacement tablets rise from 40 devices to 255.

As such, the on-premises policy exhibited a period cost increase of 27%. Whereas, the improved energy efficiency enabled by Windows 365 and the resulting alternative device strategy causes the policy costs to rise by just 6%.

By 2030, the organisation adopting the Windows 365 policy will therefore experience 19% less utility cost, paying $8,075 (table 6) in 2030 compared to $9,615 (table 2) for the on-premises annual utility costs.

In total, the Windows 365 solution electricity consumption costs are $62,096, saving $6,417 during the pathway period.

Table 6. End user computing utility costs (US$) for the Windows 365 policy

Device Type	2023 (US$)	2024 (US$)	2025 (US$)	2026 (US$)	2027 (US$)	2028 (US$)	2029 (US$)	2030 (US$)
Desktops	1,654	1,711	1,770	1,465	1,214	1,005	830	688
Notebooks	1,298	1,343	1,389	1,150	951	788	653	539
Tablets (existing)	80	83	86	71	58	47	39	32
Tablets 2-in-1 (new)	0	0	0	223	417	584	730	861
Thin clients	80	82	85	230	354	463	560	645
Monitors	4,188	4,332	4,482	4,636	4,796	4,962	5,133	5,310
Total	7,300	7,552	7,812	7,775	7,790	7,848	7,944	8,075

As before, the consumption values influence the outcome of the location based scope 2 use-phase GHG emissions. European operations produce the lowest average annual value of 14,460 kgCO_2e decreasing from 18,437 kgCO_2e initially to 10,026 kgCO_2e at the end of the period. This creates an average per capita value of 14.5 kgCO_2e.

When compared to the on-premises results, the annual abatement by 2030 is 16% or 1,912 kgCO2e. Cumulatively, the Windows 365 policy creates 115,680 kgCO2e (figure 6). The GHG emissions are equivalent to the pollution produced by 421,000 combustion car miles and requires 17 forest acres each year to remove the resulting carbon from our atmosphere.

Compared to the on-premises result of 126,164 CO_2e (figure 4), 10,484 kgCO_2e scope 2 GHG emissions are avoided. This avoids pollution equal to 39,000 car miles and requires 2 less forest acres per year for sequestration purposes.

Similar to the previous policy, the mid impact value is produced by the global operations scenario. Annual average scope 2 emissions are 20,864 kgCO_2e declining from 23,388 kgCO_2e in 2023 to 17,941 in 2030. This is equal to generating 20.8 kgCO_2e of emissions on average per user each year.

When compared to the on-premises approach, 2030 abatement reaches 16% as before, although the avoided emissions increase to 3,422 kgCO_2e due to carbon intensity differences experienced between Europe and worldwide.

Cumulatively, in a global context, the Windows 365 approach for 1,000 users generates 166,910 kgCO_2e, being 9% lower than the on-premises emissions value of 183,037 kgCO_2e (figure 4) and avoiding 16,127 kgCO_2e scope 2 emissions.

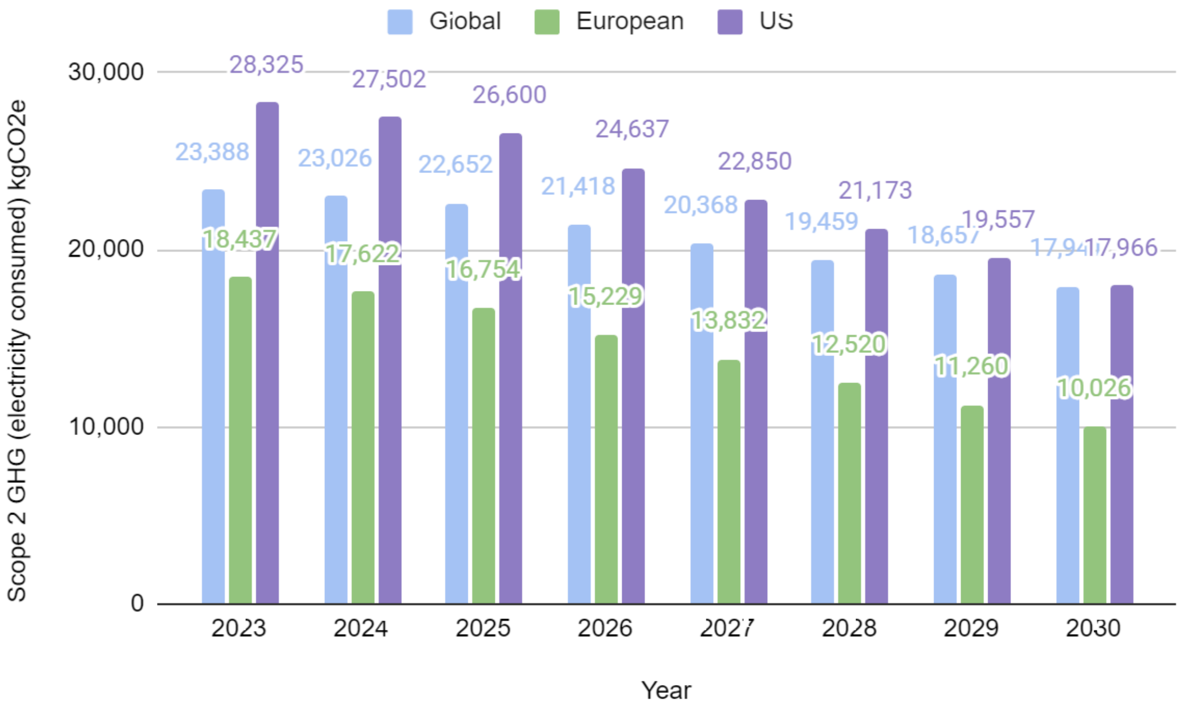
The total emissions are equivalent to driving 607,700 car miles, therefore avoiding almost 58,700 miles. Requiring 25 forest acres per year to remove the resulting carbon, a transition to the Windows 365 solution from the on-premises approach relieves 2 forest acres.

As anticipated the US location of use results once again produce the highest use-phase GHG emissions value due to the raised electricity carbon intensity in the supply grid. Average annual emissions are 23,576 kgCO_2e declining from 28,325 kgCO_2e in 2023 to 17,966 kgCO_2e by 2030 due to accelerating adoption of low carbon energy sources almost equivalent to Europe (figure 6).

This is equal to an annual average of 23.6 kgCO_2e per user during the period. The yearly reduction achieved is once again 16% by 2030, avoiding 3,425 kgCO_2e at this point. Cumulatively, the policy creates 188,609 kgCO_2e, equivalent to 686,724 car miles and requiring 28 forest acres.

As such, 17,593 kgCO2e or just over 64,000 miles are avoided when compared to the on-premises approach that generates 206,202 kgCO2e in use-phase emissions. Consequently, the Windows 365 solution requires 3 less forest acres to sequester the pollution.

Figure 6. End user computing scope 2 (electricity consumed) annual GHG emissions (kgCO_2e) for the Windows 365 policy by location of use



As noted, unlike the on-premises approach, the Windows 365 policy displaces new product scope 3 emissions until 2026 when the first 20% of devices reach the 8-year extended lifespan. Additionally, the process of replacing like-for-like devices is changed to selecting devices with lowered carbon footprints.

Because of this change in behaviour, cumulative scope 3 emissions generated by the supply chain policy decline by 55% when compared to the on-premises approach from 792,192 kgCO_2e to 357,600 kgCO_2e. As such, average annual values for the period decline from 99,024 kgCO_2e to 44,700 kgCO_2e.

Scope 3 emissions avoided during the pathway period are 434,592 kgCO2e. This is equivalent to pollution created by 1.6m combustion car miles and would otherwise require 65 forest acres each year to remove the resulting carbon from the atmosphere.

As before, the results emphasise the importance of scope 3 supply chain emissions. Using the median global conversion factor as an example, the Windows 365 approach avoids a total of 450,719 kgCO_2e. Of this, 3.6% is attributed to the use-phase reduction and 96.4% to product displacement and selecting devices using sustainability as a criterion.

While extending the lifespan of devices from 5-year replacement cycles to 8-years will reduce supply chain emissions by 37.5% per device by displacing new purchases, selection in this example is key. As noted, the thin clients replacing the desktops exhibit a 51% lower carbon footprint and the tablet devices are 65% lower.

Table 7. Windows 365 end user computing scope 3 (supply chain) GHG emissions (kgCO_2e)

Device Type	Average Scope 3 GHG per unit (kgCO2e)	2023 New Product Scope 3 Emissions (kgCO2e)	2024 New Product Scope 3 Emissions (kgCO2e)	2025 New Product Scope 3 Emissions (kgCO2e)	2026 New Product Scope 3 Emissions (kgCO2e)	2027 New Product Scope 3 Emissions (kgCO2e)	2028 New Product Scope 3 Emissions (kgCO2e)	2029 New Product Scope 3 Emissions (kgCO2e)	2030 New Product Scope 3 Emissions (kgCO2e)	Cumulative New Product Scope 3 Emissions (kgCO2e)
Desktops	221	0	0	0	0	0	0	0	0	0
Notebooks	266	0	0	0	0	0	0	0	0	0
Tablets (existing)	110	0	0	0	0	0	0	0	0	0
Tablets 2-in-1 (new)	93	0	0	0	11,904	11,904	11,904	11,904	11,904	59,520
Thin clients	108	0	0	0	7,776	7,776	7,776	7,776	7,776	38,880
Monitors	324	0	0	0	51,840	51,840	51,840	51,840	51,840	259,200
Total		0	0	0	71,520	71,520	71,520	71,520	71,520	357,600

Logically, displacing procurement cycles will reduce costs as new products are purchased less frequently. Additionally, as the Windows 365 policy enables the opportunity to procure just-in-time Cloud PCs and thin clients as well as regular Windows desktops, the expenditure will reduce further. Based upon the new 8-year procurement cycle, products begin to be purchased in 2026. As no replacement devices are required during the prior three years due to the lifespan extension, $588,000 of equipment spend has already been avoided at this point (table 8).

Table 8. Windows 365 end user computing replacement cycles and procurement costs (US$)

Device Type	2023 New Product Cost	2024 New Product Cost	2025 New Product Cost	2026 New Product Cost	2027 New Product Cost	2028 New Product Cost	2029 New Product Cost	2030 New Product Cost	Cumulative New Product Cost
Desktops	$0	$0	$0	$0	$0	$0	$0	$0	$0
Notebooks	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tablets	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tablets (new)	$0	$0	$0	$96,000	$96,000	$96,000	$96,000	$96,000	$480,000
Thin clients	$0	$0	$0	$32,400	$32,400	$32,400	$32,400	$32,400	$162,000
Monitors	$0	$0	$0	$40,000	$40,000	$40,000	$40,000	$40,000	$200,000
Total	$0	$0	$0	$168,400	$168,400	$168,400	$168,400	$168,400	$842,000

Additionally, as both policies replace 20% of computers annually when appropriate, a comparative $27,600 is saved in each subsequent year by transitioning to thin clients and 2-in-1 tablets.

The result is a cumulative spend of $842,000 for the Windows 365 policy. In total, enabled by cloud PC adoption, new device costs for the period are reduced by 46% when compared to the on-premises spend of $1,568,000, creating a saving of $726,000.

3.2.2.1 Windows policy pathway 2023-2030

For the Windows 365 policy, the emissions calculations determine that scope 2 use-phase emissions for the period 2023-2030 are 166,910 kgCO_2e if an organisation is operating on a global basis; 115,680 kgCO_2e when operating in Europe and 188,609 kgCO_2e for the US. Scope 3 supply chain values are not influenced by location and therefore are 357,600 kgCO_2e for all locations. As such, figure 7 highlights that adopting the Windows 365 policy, Europe again produces the lowest overall environmental impact due to the influence of low carbon energy supply.

Specifically, a total carbon footprint of 473,280 kgCO2e GHG emissions is caused by end user computing operations undertaken by the 1,000 user group. The value is 49% lower than the on-premises total of 918,356 kgCO2e.

In this example, because 55% of the supply chain impact is avoided, use-phase emissions proportional contribution rises when compared to the on-premises result of 14%, to represent 25% of the total carbon footprint. This ability to rebalance the dominance of supply chain emissions via device selection and displacement emissions is particularly effective. By 2050 it may be the case that the GHG contribution from scope 2 emissions will decline further due to increasing adoption of renewable energy across the globe.

As such, it is feasible to suggest that a further one quarter of total emissions created by electricity consumption may be avoided in the future simply by natural progression. The cumulative GHG emissions created by the European Windows 365 policy are equivalent to pollution caused by 1.72m miles and requires 71 forest acres to remove the resulting carbon from the atmosphere.

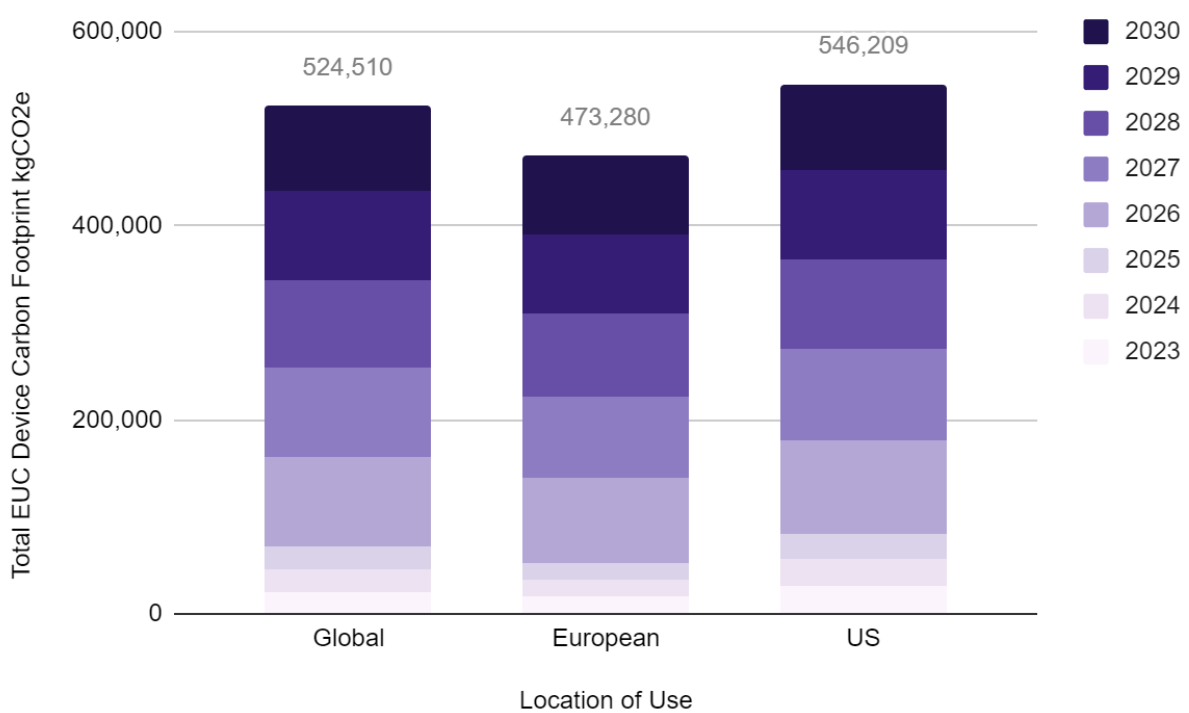
While the value remains an environmental concern, in the context of abatement the equivalent of 1.62m miles are avoided by adoption of Windows 365 ensuring that 67 forest acres are relieved every year enabling sequestration of unrelated societal emissions to be processed by photosynthesis.

As dictated by the carbon conversion factors, the US regional results produce the highest total carbon footprint of 546,209 kgCO_2e (figure 7). In this example, electricity derived emissions are responsible for 34% suggesting that similar to Europe, one-third of future emissions could be avoided by ever reducing energy related carbon intensities.

In this example, the total emissions are equivalent to 1.99m car miles and require 82 forest acres each year. Compared to the on-premises policy, 452,185 kgCO_2e is avoided during the duration. This is equivalent to avoiding 1.66m and relieving 68 forest acres.

Finally, when assessed as a global average, Windows 365 Cloud PC style end user computing operations for 1,000 users generate a total of 524,510 kgCO_2e creating a 46% reduction in total carbon footprint when compared to the on-premises approach. Abating 450,719 kgCO_2e of GHG emissions means that equivalent pollution from 1.64m car miles will be avoided; a value that would otherwise require 68 forest acres each year to sequester the carbon from the atmosphere. As anticipated, the global finding represents a median for environmental impact, being 11% above the European value and 4% below the US value. In this context, it becomes clear that when examined as a whole, while electricity consumption remains a key factor, it is embodied scope 3 emissions that offer the greatest opportunity to abate computing GHG emissions. As an example, even though the US conversion factor is currently 18% higher than the global factor, the fact that both values become equivalent in 2030 causes scope 3 supply chain emissions to account for 81% of the total global carbon footprint.

Figure 7. Windows 365 Total end user computing device carbon footprint (kgCO_2e) by location



The rebalancing of the dominance of new product based impacts is also reflected within the profit metrics produced by the Windows 365 results. Displacing procurement cycles by 36 months causes the recurring annual new product expenditure to become zero during the initial three years (figure 8).

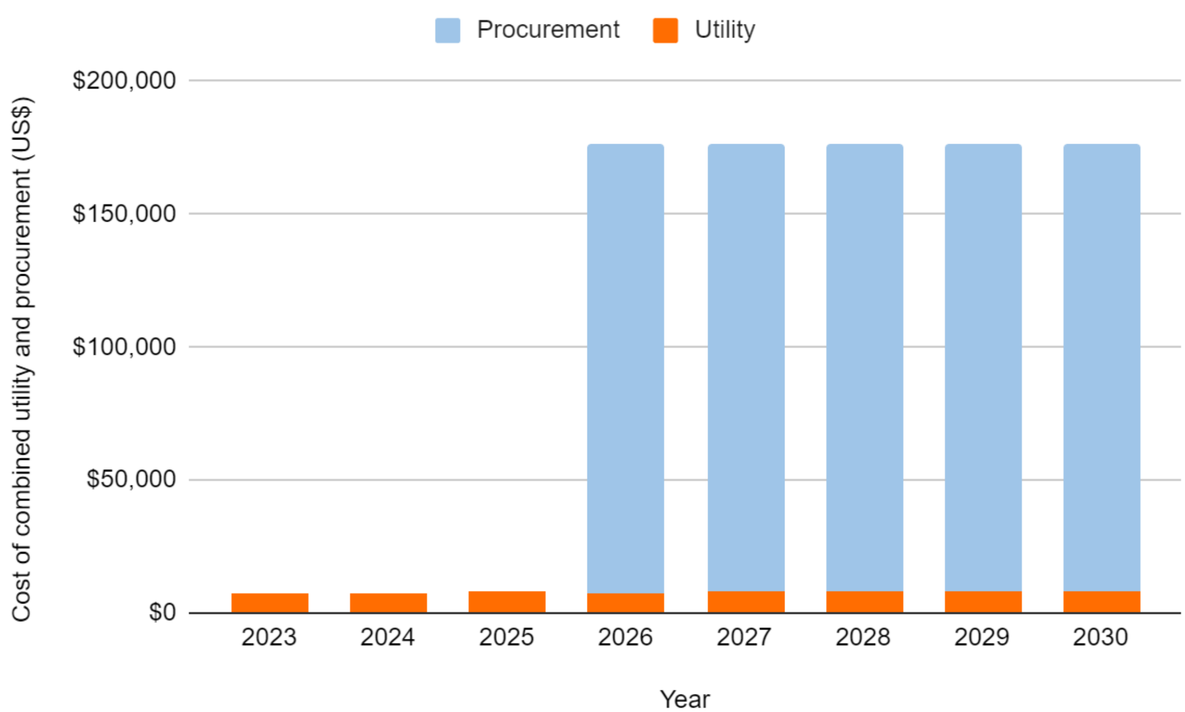
The consequence being that of the total period expenditure of $904,096, 17% is attributed to utility spending.

This is an increase from 4% exhibited by the on-premises approach. As such, setting aside the environmental impact, whilst electricity costs decline with the Windows 365 solution compared to the on-premises approach, energy efficiency remains key to managing cost sources in this model.

While the total costs are reduced by $732,417 when compared to the on-premises solution, the proportional representation of utility spend increases by 13% from 4%

As such, for the Windows 365 policy total utility and hardware expenditure declines by 45%, creating average annual costs of $113,012 compared to $204,564 for the on-premises solution.

Figure 8. Total end user computing combined hardware and utility costs (US$) for the Windows 365 policy



3.3 Additional GHG Abatement Opportunities with Windows 365

The GHG pathways substantiate that significant environmental gains are achieved by transitioning to Windows 365. As noted, the policies are designed to enable valid comparison by continuing with similar strategies that produce very different outcomes simply based upon different energy efficiency and parameters concerning procurement and retention.

However, other opportunities exist to further reduce end user computing GHG emissions. These include bring your own PC (BYOPC) schemes that limit device production by encouraging employees to have just one computer for both work and personal use. Plus, technology enabled remote working schemes that reduce commuting emissions as employees travel to work less frequently.

As such, the following section uses scientific data to offer abatement examples defined by both incremental sustainable IT strategies.

3.3.1.Windows 365 plus BYOPC Policy Scope 3 Supply Chain Emissions

BYOPC policies enable employees to use their personal computer as a work device. Instead of buying end user computing hardware such as a notebook or tablet, companies pay a fee to staff to cover the cost of a device.

To achieve this, the participating organisation requires an IT solution that delivers secure access to company systems to ensure a positive ongoing productivity experience, systems security and the ability to ensure each digital workspace is maintained.

Microsoft's Windows 365 offers this ability and can therefore be considered an integral component when considering BYOPC schemes.

From an environmental perspective, adopting BYOPC schemes enables a significant outcome in relation to supply chain abatement. In most cases, it is reasonable to suggest that users will revert from using two separate devices and own just one device due to both convenience and financial benefit.

This means that computers that would have been purchased by the employer are no longer required. As such, total displacement is experienced from an organisational perspective.

As noted in the methodology, in this example the BYOPC policy is applied to mobile devices only. This is based upon the rationale that continued office based working will be facilitated by the transition from desktops to thin clients.

As with the Windows 365 policy, replacement of devices begins from 2026 onwards when the 8-year extended retention period ends for 20% of the estate. Using the popularity of device type statistics previously noted, ongoing mobile device energy consumption and concomitant scope 2 GHG emissions are calculated based upon BYOPC users beginning to use their own notebooks (60%) and tablets (40%) for business activities.

Table 9. Windows 365 + BYOPC end user computing scope 3 (supply chain) GHG emissions ($kgCO_2e$)

Device Type	2023 New Product Scope 3 Emissions (kgCO2e)	2024 New Product Scope 3 Emissions (kgCO2e)	2025 New Product Scope 3 Emissions (kgCO2e)	2026 New Product Scope 3 Emissions (kgCO2e)	2027 New Product Scope 3 Emissions (kgCO2e)	2028 New Product Scope 3 Emissions (kgCO2e)	2029 New Product Scope 3 Emissions (kgCO2e)	2030 New Product Scope 3 Emissions (kgCO2e)	Cumulative New Product Scope 3 Emissions (kgCO2e)
Desktops	0	0	0	0	0	0	0	0	0
Notebooks	0	0	0	0	0	0	0	0	0
Tablets (existing)	0	0	0	0	0	0	0	0	0
Tablets 2-in-1 (new)	0	0	0	0	0	0	0	0	0
Thin clients	0	0	0	7,776	7,776	7,776	7,776	7,776	38,880
Monitors	0	0	0	51,840	51,840	51,840	51,840	51,840	259,200
Total	0	0	0	59,616	59,616	59,616	59,616	59,616	298,080

For illustrative purposes, it is assumed that the users will either already have or would purchase a mobile computing device regardless of the BYOPC scheme.

As such, the forecast of scope 3 supply chain emissions for mobile computing devices focuses upon the most impactful change in behaviour driven by displacement strategies known as the 'single device' approach. It is therefore considered that the supply chain emissions of the secondary business mobile computing device are entirely avoided.

Consequently, as highlighted in table 9, annual replacement new device supply chain emissions begin in 2026 producing 59,616 $kgCO_2e$ scope 3 GHG emissions each year. Cumulatively, this generates 298,080 $kgCO_2e$.

The total is 62% lower than the supply chain impact created by the on-premises policy (792,192 $kgCO_2e$) and a further 17% improvement when compared to the Windows 365 policy (357,600 $kgCO_2e$).

While speculative due to the assumptions used with regards to employee device ownership by type, scope 2 emissions for the BYOPC scenario will not represent an improvement in this example when compared to the Windows 365 only solution. This is because rather than all mobile computers converting to highly energy efficient 2-in-1 tablets, the electricity consumption calculation includes 60% adoption of notebooks within those participating in the BYOPC scheme. As such, only 40% of new mobile devices are tablets.

Consequently, the resulting cumulative electricity consumption of 489,662 kWh (table 10) does decline by 8% when compared to the on-premises policy (533,070 kWh). However, a marginal rise of 1% occurs when compared to the Windows 365 results of 485,063 kWh. As such, the scope 2 emissions value for the BYOPC solution is 168,433 $kgCO_2e$, compared to the Windows 365 only solution generating 166,910 $kgCO_2e$.

Table 10. End user computing electricity consumption (kWh) for the Windows 365 + BYOPC policy

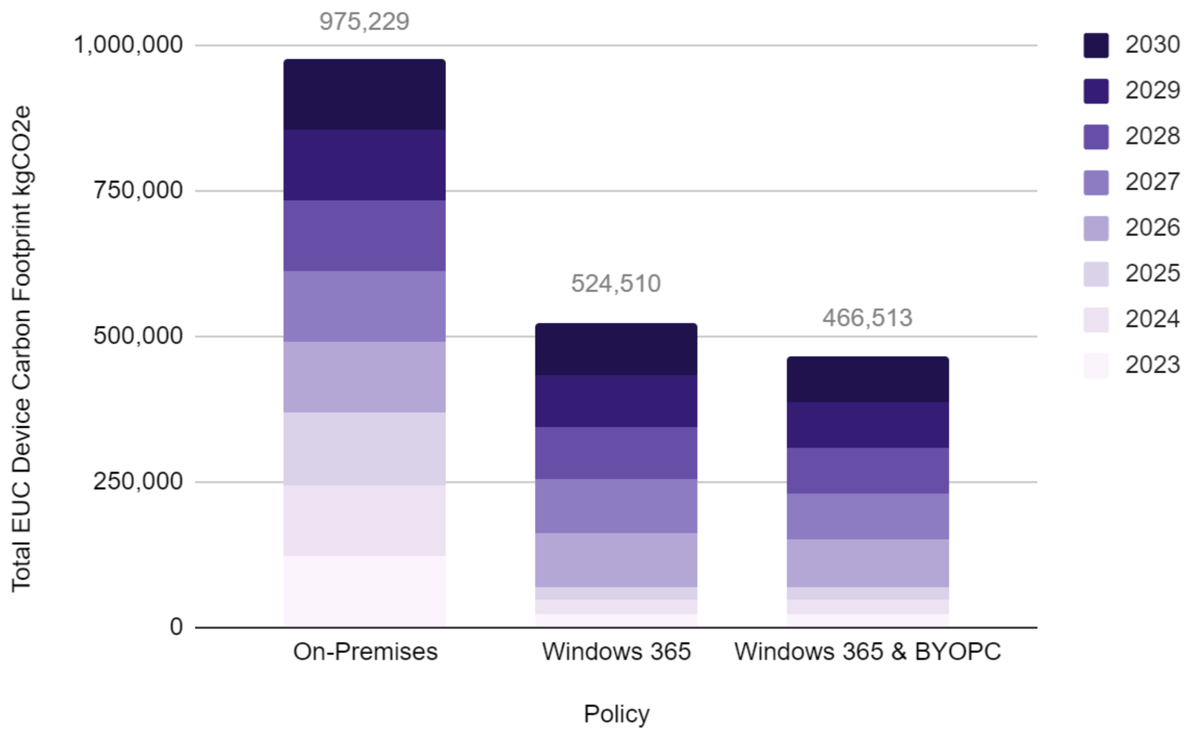
Device Type	2023 kWh/y	2024 kWh/y	2025 (kWh/y)	2026 Units per 1,000 users	2026 kWh/y	2027 Units per 1,000 users	2027 kWh/y	2028 Units per 1,000 users	2028 kWh/y	2029 Units per 1,000 users	2029 kWh/y	2030 Units per 1,000 users	2030 kWh/y
Desktops	14,538	14,538	14,538	256	11,630	205	9,313	164	7,451	131	5,951	105	4,770
Notebooks	11,407	11,407	11,407	541	10,640	504	9,913	468	9,205	434	8,536	402	7,907
Tablets (existing)	704	704	704	48	564	38	446	30	352	24	282	19	223
Tablets 2-in-1 (new)	0	0	0	51	706	98	1,356	142	1,965	182	2,519	219	3,031
Thin clients	701	701	701	104	1,822	155	2,716	196	3,434	229	4,012	255	4,468
Monitors	36,800	36,800	36,800	800	36,800	800	36,800	800	36,800	800	36,800	800	36,800
Total	64,150	64,150	64,150	1800	62,162	1800	60,544	1800	59,207	1800	58,100	1800	57,198

Despite the marginal increase in scope 2 emissions, the total abatement is significant. As highlighted in figure 9, the BYOPC policy offers a feasible total carbon footprint reduction of 52% when compared to the on-premises solution and 11% in total when compared to the Windows 365 solution within the pathway period.

As such, in this example the Windows 365 plus BYOPC delivers a total abatement of 508,716 kgCO2e when compared to the on-premises policy. This is equivalent to avoiding pollution created by driving 1.85m car miles and would otherwise require 76 forest acres to remove the resulting carbon from the atmosphere.

As demonstrated, when adopted alongside Windows 365, BYOPC offers a further effective tool to encourage responsible consumption and meaningfully drive climate action through the medium of sustainable IT strategies.

Figure 9. Total end user computing device carbon footprint ($kgCO_2e$) by policy



i) On-Premises: 1,000 users with local operating system devices and locally processed productivity applications. Devices refresh in 5-year procurement cycles replacing 20% of the end user computing estate. Replacement devices are like-for-like with average carbon footprint devices selected.

ii) Windows 365: The policy adopts Windows 365 for all 1,000 users accessing both desktop and applications via cloud PCs. Device useful life span is consequently increased by 3 years to 8 years. Devices are therefore refreshed in 8-year procurement cycles, again replacing 20% of the end user computing estate during each phase. Replacement devices are selected based upon having the lowest carbon footprint.

iii) Windows 365 & BYOPC: The 1,000 user company has adopted the Windows 365 policy. Device refresh reflects the Windows 365 policy. Desktop style computers continue to be purchased by the organisation, unlike the Windows 365 policy, new company owned replacement mobile devices (notebooks and tablets) are not purchased and the scope 3 value is realised as zero. This is based on the assumption that employees will already own or intend to purchase a personal device and as such total displacement of secondary business mobile devices is achieved.

3.3.2. Commuting to Access IT (CAIT) Impact: Scope 3 GHG emissions

Transport generates 14% of global greenhouse gas emissions and is therefore an important source of abatement to drive climate action. Research determines that employees commute on average 44 miles per working day and work remotely on average for 2-days per week [6].

Globally, the average scope 3 commuting emissions generated by visiting the workplace for 60% (3-days) of the working week is 1,258 $kgCO_2e$ [6]. As such, encouraging employees to increase remote working days will deliver significant positive impact to sustainable transport strategies enabled by IT solutions such as Windows 365.

In order to highlight the positive environmental impact of remote working enabled by IT, two annual scope 3 employee commuting emissions values are calculated, each with four outcomes.

The first is based upon the assumption that only employees with mobile computing devices will exercise the ability to work remotely.

The second will assume that all employees will introduce remote working into their routine.

In both examples, remote working patterns include zero remote days (0%) to set a baseline and the one, two and three remote working days per week.

As highlighted by figure 10, with all employees exercising the option to work remotely, each additional day reduces emissions from the zero-day baseline of 2,097,000 $kgCO_2e$ by an incremental 20% reaching 838,800 $kgCO_2e$. In this scenario, an incremental annual abatement of 419,400 $kgCO_2e$ is achieved for each additional remote working day.

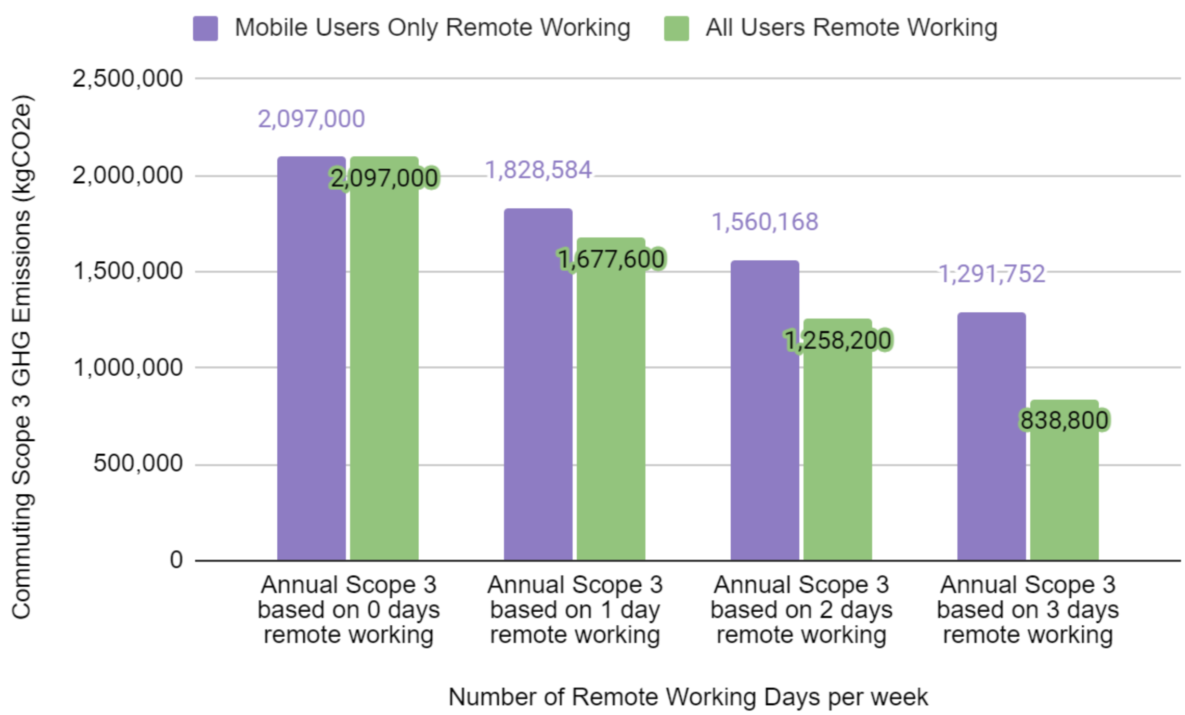
As an example, should all employees work remotely for 3-days per week then 1,258,200 $kgCO_2e$ is avoided per year. This is equivalent to pollution produced by over 4.5m car miles and would otherwise require just over 1,500 acres of forest to remove the carbon from our atmosphere.

In comparison, should the remote working capability be exercised by workers using mobile computing devices, then the commuting emissions avoidance declines to a 13% incremental reduction per year based upon the number of remote working days.

In this scenario, working three days remotely creates an annual abatement of 805,248 kgCO2e. This is equivalent to over 2.9m car miles and requires over 960 forest acres.

While remote working practices will be defined by job role and circumstance, it is clear that organisations adopting Windows 365 have a significant opportunity to further drive climate action by reducing commuting GHG emissions.

Figure 10. Scope 3 commuting emissions (kgCO_2e) by remote working policy



Chapter 4: Summary

4.1 Policy Comparison

It is substantiated by the initial experiment that transitioning to Windows 365 cloud PC solutions from on-premises operations reduces endpoint electricity consumption by 12% for notebooks and 6% for desktop computers. This is achieved by local processing activities that usually increase component power draw being alleviated as workloads are conducted by the cloud PC infrastructure located within Microsoft data centres.

In isolation, this finding will abate individual annual average desktop and notebook scope 2 GHG use-phase emissions by 1.07 $kgCO_2e$ and 0.99 $kgCO_2e$ when utilising the current global electricity to GHG emissions factor.

This may at first seem insignificant. However, as there are 4.2 billion computer users in the world, removing an average of 1$kgCO_2e$ for every user avoids emissions equivalent to 15.3bn combustion car miles annually. In context, this quantity of pollution requires over 5m forest acres to remove the resulting carbon from the atmosphere every year. Such a forest would entirely cover the landmass of El Salvador.

However, 100% user diffusion of such solutions is theoretical. Alternatively, examining results on a smaller scale is credible. Additionally, including associated changes in IT policy behaviours that would not be feasible without innovative technologies such as Windows 365, allows valid abatement values to be calculated. Doing so clearly determines opportunities for public and commercial sector companies to adopt and realise the positive impact of sustainable IT strategies. With meaningful end user carbon footprint information to support decision making, the goal of responsible IT consumption and subsequent climate action becomes tangible. Such resonant results become key to corporate social responsibility (CSR) and environmental, social and governance (ESG) strategies and as such, supporting the UN sustainable development goals becomes part of everyday operations.

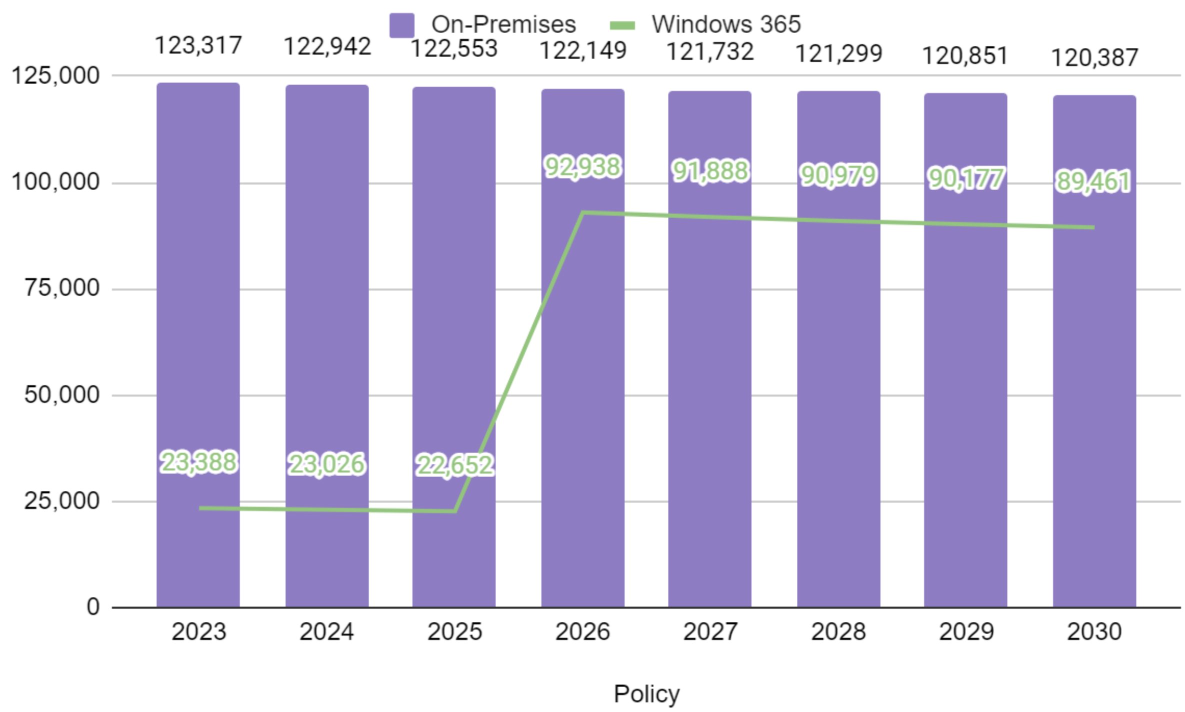
The 1,000 user GHG pathways detailing the influence of electricity consumption and supply chain changes provide meaningful information. It may be that an organisation interested in Windows 365 to support sustainable IT strategies does not have 1,000 employees. Instead, it could be 5,000 or even 250 users. The point being, that the pathways can be divided or multiplied to match any number of employees (see per capita results below). This is feasible because the data is generated based upon a mixed end user computing environment that caters for all device variations and reflects the most common proportional representation of computer choice among businesses.

Created to forecast emissions during the critical period between 2023-2030 when societal emissions must be reduced to halt global warming rising above 1.5^{o}C, two comparisons are outlined to highlight the impact of 'doing nothing' or changing behaviours that will contribute to a more sustainable future.

The pathway of apathy is represented by the 'on-premises policy' whereby business as usual continues. Computing occurs locally upon the endpoint computer and devices are refreshed in 5-year cycles. The 'Windows 365 policy' represents the opportunity to 'be the change'. In doing so, by transitioning the entire workspace to the cloud, significant GHG abatement is realised through improved energy efficiency, hardware displacement, device selection based upon sustainability as a criterion and where applicable, BYOPC and remote working schemes.

As such, it is clear from the findings that the Windows 365 policy offers a significant opportunity to deliver positive environmental impact. As highlighted in figures 9 and 11, the transformational cloud PC based policy reduces total GHG emissions by 46% as a global average when compared to the on-premises policy.

Figure 11. Total annual end user computing device carbon footprint (kgCO_2e) by policy



This is achieved by combining both the energy reduction and supply chain displacement opportunities uniquely enabled by a Windows 365 solution.

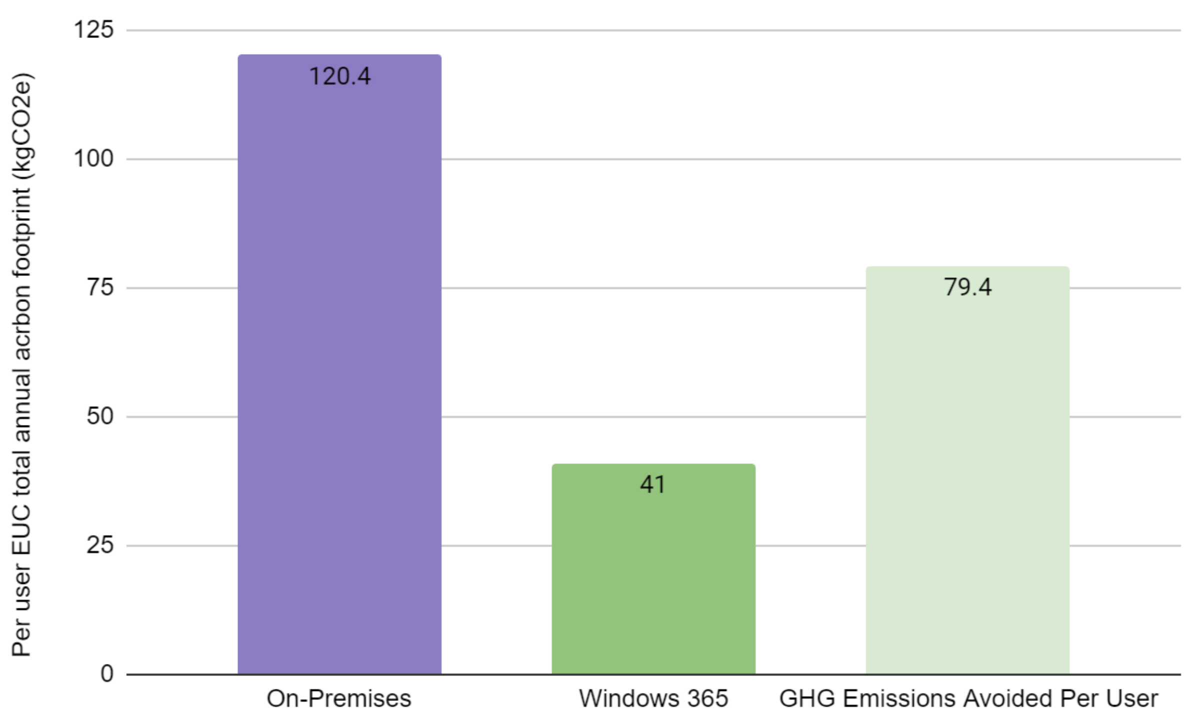
The overall abatement for the period is 450,719 kgCO2e having declined from the 975,229 kgCO2e carbon footprint of the on-premises policy to 524,510 kgCO2e (figure 9). As noted, the avoided emissions are equivalent to 1.64m car miles. In context, such a distance travelled circles the Earth sixty-six times.

Looking ahead, in 2030, when all of the end user computing estate has been refreshed and devices are now retained for 8-years, the per capita impact of end user computing is entirely transformed to support the attainment of sustainability goals.

Individual average annual average scope 2 electricity emissions decline by 16% from 21.4 kgCO_2e per user for the on-premises approach, to 17.9 kgCO_2e for the Windows 365 strategy. This is caused by replacing notebooks and desktops with low energy endpoint computers such as tablets and thin clients plus reduced local power draw benefits enabled by cloud computing. Similarly, having selected new devices using sustainability as a criterion and extending the useful life span by 36-months, annualised scope 3 supply chain emissions have declined by 77%. Specifically, the original blend of devices used by the 1,000 users equates to 99 kgCO_2e per year of ownership. For the new strategy, the low carbon footprint devices and increased retention periods reduce this blended value to just 23.1kgCO_2e.

Significantly, enabled by Windows 365 adoption, the per capita annual total end user carbon footprint reduces from 120.4 kgCO_2e to 41 kgCO_2e (figure 12).

Figure 12. Annual per capita end user computing device carbon footprint (kgCO_2e) by policy

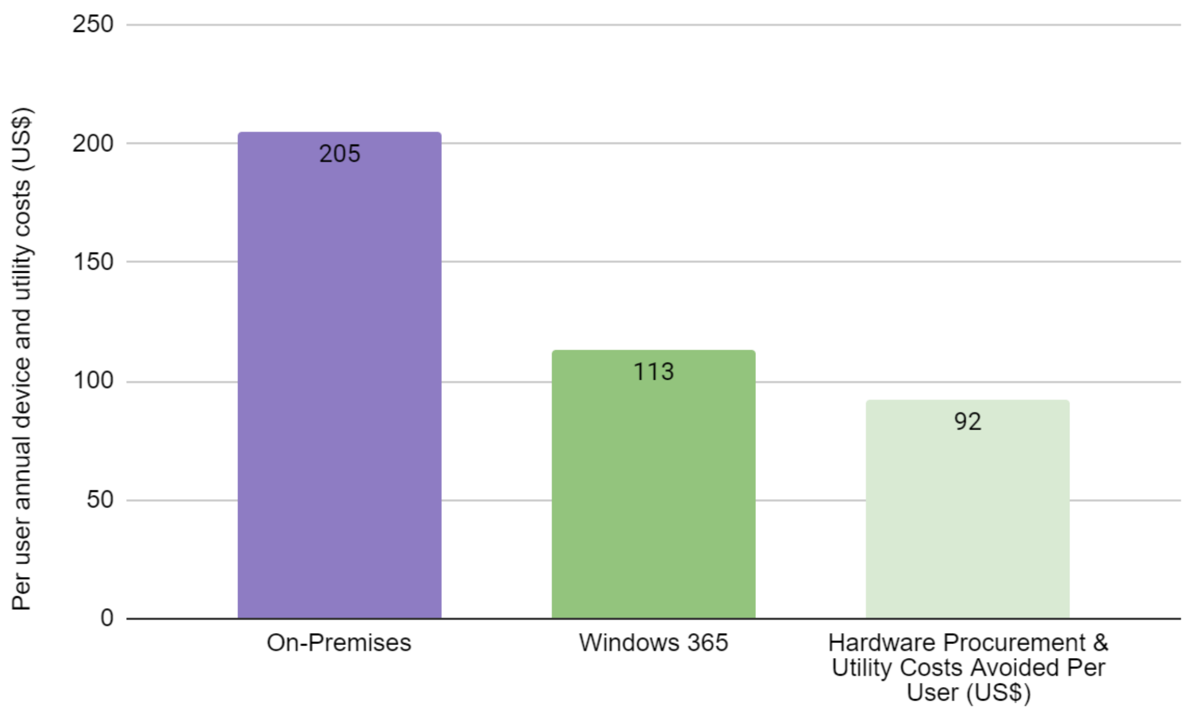


Circling back to the initial theory of 1kgCO_2e per user abatement, it is clear that the reality when considering all abatement opportunities enabled by the Windows 365 policy, the impact is far greater. In fact, the single user carbon footprint reduces by 66% avoiding 79.4 kgCO_2e per year.

Hypothetically applying this to the 4.2bn users generates an annual abatement 333,480,000,000 kgCO2e. Such a vast quantity of emissions would require 400,176,000 mature forest acres to remove the resulting carbon from the Earth's atmosphere. In context this area is equivalent to over 1% of the planet's entire land mass and would cover an area the size of Mongolia.

While significantly impactful from a planet perspective, it is recognised that barriers to diffusion of sustainable IT strategies exist. One such barrier is the misconception that such policies generate incremental cost [4]. Research has proven that in fact the reality is opposite with utility and hardware costs being driven down by electricity and procurement efficiencies [7, 10, 12].

Figure 13. Annual per capita end user computing device hardware and utility costs (US$) by policy



As previously noted, for the 8-year pathway period annual utility and new product costs are reduced by 45%, creating a total saving of $732,417. Specifically, annual average combined costs for the Windows 365 policy are $113,012 compared to $204,564 for the on-premises solution.

From a per capita perspective, the new sustainability strategy reduces individual annual computer procurement and electricity consumption costs by the same percentage from $205 to $113, saving operational and capital expenditure of $92 per user each year.

With this in mind, it is suggested that in the spirit of the triple bottom line of sustainability accounting, if encouraging responsible consumption to support the UN sustainable development goals reduces total GHG emissions by as much as 66% and costs by 45%, then whether key performance indicators are rooted in planet, profit or a combination of both, the research determines positive outcomes are available for all parties.

Chapter 5: Conclusions

The research question asks, "Can modern work applications and endpoints abate end user computing greenhouse gas emissions?" As the research determines, the answer is quite clearly, yes.

Exploring beyond the affirmation, it is in fact reasonable to state that as demonstrated, adopting end user computing strategies based upon Windows 365 will reduce GHG emissions by 46% during the period from now until 2030 and by 66% ongoing.

As highlighted, doing so at scale is arguably critical if the UN gap strategy is to be achieved by leveraging end user computing to reduce societal greenhouse gas abatement. Achieving the goals outlined by the research, such as energy consumption reduction, procurement displacement, device selection using sustainability as a criterion, BYOPC and remote working, contribute to the sustainable development goals.

Specifically, inspecting devices for initial low carbon footprints drives responsible production as manufacturers strive to reduce impact from material acquisition, manufacturing and distribution. Retaining devices for longer periods and driving down electricity consumption reduces demand and scope 2 emissions supporting the basics required to achieve responsible consumption. Combining this with increased working to reduce commuting emissions ensures that climate action occurs on a daily basis.

In conclusion, it is reasonable to state that modern work applications and endpoint computers not only abate GHG emissions, they are perhaps critical to securing a sustainable future. This is because human-computer interaction has become part of modern existence and cannot be avoided. In such circumstances the responsibility is upon us, the user, to ensure that the actions we take today safeguard the environment of tomorrow.

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About Px³

Px³ is an award winning research focused IT consulting organisation specialising in sustainability and specifically the reduction of GHG emissions created by the way people work today. Our unique services enable global IT manufacturers, software vendors, cloud computing service providers, technology distributors, value added resellers plus 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, Px³ framework, cTEC methodology, Dynamic Carbon Footprint and Silent Sole certification name and icon are copyright of Px³ Ltd. All practices 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.

The United Nations notes, 'The Global Goals can only be met if we work together. International investments & support is needed to ensure innovative technological development. To build a better world, we need to be supportive, empathetic, inventive, passionate, and above all, cooperative.' For information technology to drive SDG 13 Climate Action then SDG 17 Partnership for the goals is essential. Without cooperation we cannot achieve SDG12 Responsible Consumption and Production. At Px³ our ethos reflects this. When asking IT stakeholders to rank the importance of climate change from 1-10, the average response is '9'. Whilst this identifies a passion for action, many organisations don't feel equipped to make the bridge between IT & climate action.

We empathise with this complex problem and use innovation to reveal that 'Great IT can also be Green IT'

To support responsible production, we conduct scientific research measuring the environmental impact of products & services produced by global technology companies. The rationale being that these organisations enable 4.2bn computer users to be productive or enjoy digital content. From a responsible consumption perspective, we help these companies to produce material explaining why their offerings meet SDG12 criteria. We also work in partnership and directly with their customers globally to drive behavioural changes that reduce IT supply chain, use-phase & end of life treatment emissions. As an example, our applications and consultants assist companies to select computers with the lowest carbon footprint, to measure their current IT carbon footprint and to realise potential sustainable IT strategies that enable positive change & ultimately GHG emissions abatement. This may be as simple as keeping devices for longer periods to reduce demand for the 460m new end user computing devices produced annually.

Such change is what ultimately drives SDG 13 Climate action. We've measured and advised people using almost 5m computers to date. As a result, as each year passes companies reduce their environmental footprint caused by IT.

We are achieving our goal to cumulatively abate 10,000,000 kgCO_2e of GHG emissions every year via the diffusion of sustainable IT. In fact, as a result of empathy, support, innovation and cooperation, by 2035, carbon requiring the photosynthesis of 250,000 acres of forest will no longer enter our atmosphere. In context, that's a forest equivalent to 3.9m tennis courts.

We cannot do this without embracing SDG 17 partnership for the goals. If our passion isn't shared by manufacturers, vendors and customers then our research and consulting will not be adopted and diffused. And that's why Px³ considers SDG 17 to be the binding element that enables us all to realise our ultimate goal of Climate Action. As such, we collectively thank our current and prospective ecosystem of companies that utilise Px³ services to create a more sustainable future.

About the Author

Justin Sutton-Parker is a sustainable information technology professional. As a MBA in Sustainability & PhD Doctorate researcher for Computer and Urban Science with the University of Warwick and Warwick Business School, Justin regularly publishes empirical research in the world's leading scientific computing and environmental journals. Specialising in the field of information technology greenhouse gas abatement, Justin conducts commercial research for national government and over one dozen of the world's leading computer manufacturers, software vendors, cloud computing service providers, services organisations and internationally renowned third-party environmental certification organisations.

Responsible for empirical research within the field of sustainable IT, such as meaningful commercial computing typical energy consumption (cTEC) calculation, alternative operating system energy and concomitant greenhouse gas emissions reduction and the invention of the dynamic carbon footprint, Justin's research represents the foundation for research and consulting services, applications and frameworks delivered and used by Px³.

A regular public speaker, Justin is also editor, columnist and contributor for sustainability focused consumer and national press publications such as My Green Pod, having published the world's first mainstream magazine entirely dedicated to sustainable IT.

Whether via academic, commercial or social media channels, Justin specifically promotes the adoption of 4 simple steps to achieving a lower IT carbon footprint. These include low carbon footprint devices, green data centres, remote working to reduce commuting and the reduction of e-waste via displacement and circular economy strategies.

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