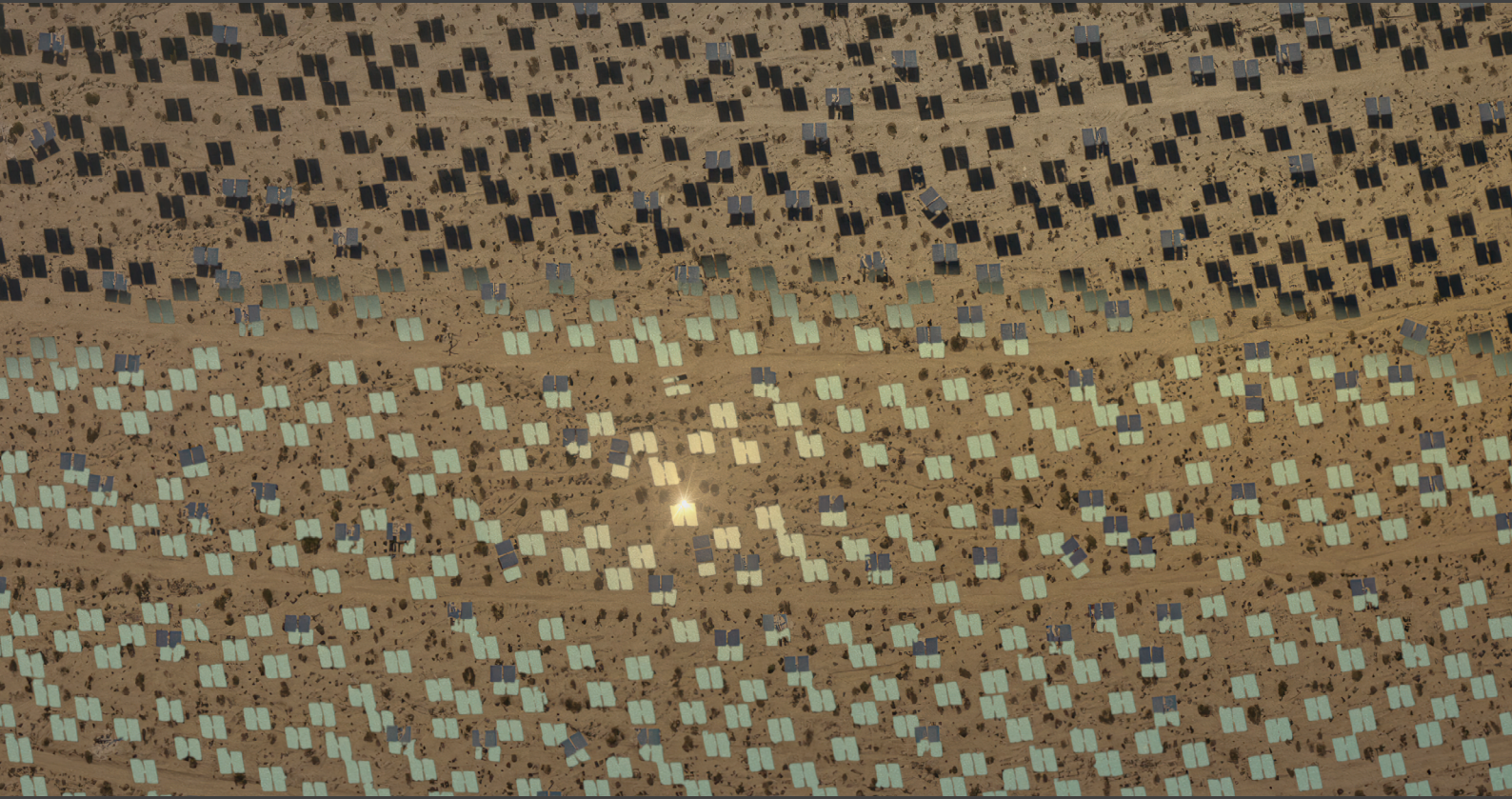




ForesightLAB



Sustainability Impacts of Convergent Technologies in the UK Creative Industries

A Foresight Lab Report prepared by Arup

April 2025

Babet Nieman, Shrey Sood, Rhiannon Williams, Florence Mansfield,
Brian Tarran and Rishi Coupland

ARUP



THE UNIVERSITY
of EDINBURGH



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The CoSTAR Foresight Lab

Driven by the UK's leading Creative Industries experts, the [CoSTAR Foresight Lab](#) is researching the adoption, use and impact of new, emergent and convergent technologies in gaming, TV, film, performance and digital entertainment.

Our findings will inform research, development and innovation across the Creative Industries, including the R&D taking place through the convergent screen technologies and performance in real time (CoSTAR) programme, the UK R&D network for creative technology.

[CoSTAR](#) is a £75.6 million national R&D network of laboratories that are developing new technology to maintain the UK's world-leading position in gaming, TV, film, performance, and digital entertainment. Delivered by the UKRI Arts and Humanities Research Council, the programme is supporting new innovations and experiences that will enrich the UK's Creative Industries, economy, and culture. The network comprises the National Lab, the Realtime Lab, the Live Lab, the Screen Lab and the Foresight Lab. CoSTAR is funded through UK Research and Innovation's Infrastructure Fund, which supports the facilities, equipment and resources that are essential for researchers, businesses, and innovators to do groundbreaking work. You can find out more by visiting www.costarnetwork.co.uk.

Foresight Lab partners and contributors

Core Partners:

Prof Jonny Freeman; Jac Sanscartier (Goldsmiths, University of London)
Prof Frauke Zeller; Prof Melissa Terras MBE; Dr Suzanne R Black (University of Edinburgh)
Prof Graham Hitchen; Dr Ekaterina Tarnovskaya; Dr Vicki Williams (Loughborough University)
Rishi Coupland; John Sandow; Brian Tarran (BFI)

Delivery Partners:

Florence Mansfield (Arup)
Prof Hasan Bakhshi MBE; Dr Tom Cahill-Jones; Prof Giorgio Fazio; Dr Sarah Najm (Creative Industries Policy and Evidence Centre)
Brendan Miles (Data Thistle)
Chiara Badiali; Natalie Highwood; Alison Tickell (Julie's Bicycle)
Noemi Ponzoni; Anna Stewart; Lewis Turner-Brown (i2 media research)
Leon Forde; Marta Moretto; Emma Openshaw; Peter Cobb; Joshua Dedman (Olsberg•SPI)
Patrick Bradley (Station12)
Alice Fearn; Daniel Hodgkin; Luke Taylor (Verian)

The Foresight Board:

Prof Dave Bull; Prof Darren Cosker; Sarah Ellis; Steve Jolley; Gaby Jenks; Prof Greg Maguire; Prof Alex McDowell;
Prof Sylvia Pan; Dr Romana Ramzan; Bill Thompson; Dr Lincoln Wallen; Nell Whitley; Deborah Williams OBE

The Lab is administrated by Petra Lindnerova and Tom Steer.

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Foreword by Prof Andrew Chitty

The CoSTAR Network was established to underpin the UK's national R&D effort in those technologies that increasingly power the Creative Industries; to ensure that the UK remains a global centre for screen production in an increasingly virtual world. We knew that in that world environmental sustainability, and decarbonisation specifically, would be absolutely central to the mission. The UK has committed to delivering net zero emissions by 2050. The Creative Industries, as a UK economic powerhouse, has a major role to play in ensuring this climate commitment is met.

As the sector moves to embrace the promise and potential of convergent technologies – from virtual production and artificial intelligence to augmented and extended realities and the metaverse – the focus, always, needs to be on how new methods of production and new creative formats can deliver the performance benefits the sector demands in line with the necessary carbon efficiencies. We must not assume that advanced technologies, from AR to AI, necessarily mean reduced carbon.

The early adoption of virtual production (VP) methods during the Covid-19 pandemic led to some ambitious statements of the environmental benefit of LED volumes versus traditional on-location filming. Comparison of the carbon footprints of virtual stages with the global travel, transport and power consumption of a large movie cast and crew produced claimed savings of “up to 50%”. Now, with a greater understanding of where VP workflows sit within the complex digital architecture of a whole production, these initial calculations look simplistic. A greater understanding of carbon impacts, of the role of data flows over a whole production lifecycle and an acknowledgement that, currently, AI technologies may be increasing rather than decreasing carbon consumption mean that there is a lot of urgent work to do.

This report, prepared by Arup in partnership with the CoSTAR Foresight Lab, sets out a way for the Creative Industries to become champions of sustainable innovation, and that this will require a real commitment to directive industry leadership, transparent data reporting and analysis, and a focus on energy-efficient solutions that embed the principles of a circular economy in a way that has just not been there to date. It will also mean the Creative Industries finding common cause with other sectors in understanding and influencing directly the behaviours of data centre operators, now recognised as one of the fastest-growing sources of carbon emissions, already exceeding that of air travel or maritime trade. The report presents a realistic range of actions that organisations and individuals can take up, supported by case study examples of sustainable practice, and highlights research gaps for the sector, and others, to pursue in areas from AI and workflows to hardware lifecycle analysis.

I urge colleagues across the Creative Industries to read this report, to absorb its implications and to carry forward its recommendations. The time calls for leadership that shifts mindsets, builds cross-sector relationships and advocates for greener, less carbon-intensive productions. But willing this will not make it happen. We need rapid research and engineering analysis to develop data and reporting frameworks that improve transparency and performance, and a commitment to strategic R&D of the type CoSTAR was created to pursue. To deliver on the sector's ambitions to decarbonise demands action, pressure and a rethink of how technology and services are developed, delivered and regulated to reduce energy and resource consumption and waste.

Professor Andrew Chitty
Chair, CoSTAR Network

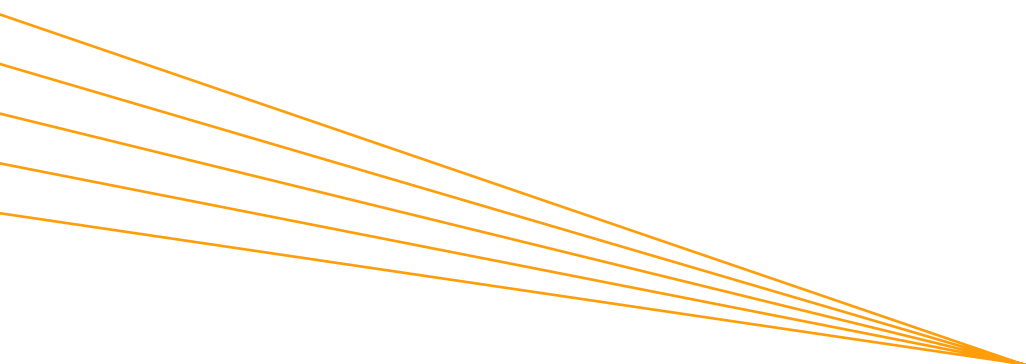
Foreword by Timothy Snelson

Technology is reshaping and revolutionising the UK Creative Industries, offering new ways to create and consume content and presenting novel creative business models. But alongside advancements in AI, virtual and augmented reality, and blockchain come critical challenges in understanding and mitigating the carbon footprint of these technologies. This report examines how these technologies, and others, are being adopted across film, music, theatre, events and online gaming and delves into their associated positive and negative sustainability (carbon) impacts. It explores the existing gaps in knowledge when it comes to measuring, reporting and reducing carbon emissions associated with the implementation of these technologies.

The Creative Industries must undergo a fundamental shift in managing environmental impacts as they integrate emerging technologies with traditional methods of creation. Top-down leadership is needed to drive innovation and systematic change in carbon management, and decision-making must be based on accurate data that understands the full impact of new technology and innovation. Integrated solutions, combining technological innovation, policy frameworks, and sustainability-driven decision-making will be essential for guiding the Creative Industries toward a just and green transition.

The research and analysis consolidated in this report aims to set out a pathway for the future of the Creative Industries, one that harmonises innovation, creativity, and sustainability.

Timothy Snelson
Media sector director, Arup



Executive summary

Convergent technologies are empowering the UK Creative Industries to reimagine the ways content is created and consumed. Virtual production and virtual spaces, artificial intelligence, and new forms of hardware and wearables present opportunities to rethink and revolutionise ways of working and explore new forms of engagement. But how might these technologies help – or hinder – the Creative Industries' ambition to put itself on a more sustainable footing?

This report sets out to answer that question. Arup, in partnership with the CoSTAR Foresight Lab, has investigated how the Creative Industries landscape will be reshaped by convergent technologies in the coming years, with a particular focus on how these technologies will require businesses to rethink and redefine their sustainability strategies.

Based on a wide-ranging, mixed-methods study, the report identifies proactive and specific actions organisations can take to mindfully manage some of the environmental impacts of convergent technologies, with case studies demonstrating successful implementation of sustainable practices. It surfaces three clear themes, which cut across technology types and applications, and which are critical calls to action for driving sustainable progress across the Creative Industries:

1. Directive industry leadership

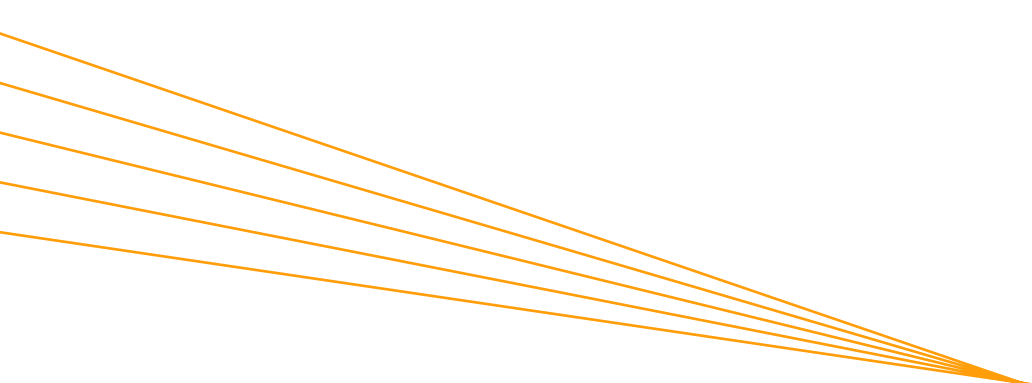
There is a pressing need for top-down direction when it comes to sustainability. In the UK Creative Industries, as in other sectors, there needs to be a transformative approach to leadership, with a focus on driving innovation, collaboration, and systematic change to enable creative businesses and creative workers to cut emissions and ensure sustainable futures.

2. Data acquisition and reporting

To ensure a sustainable future for the UK Creative Industries, a data-driven approach is critical. Acquiring accurate and comprehensive data on carbon emissions, for example, will enable the sector to truly understand the environmental impact of the use of convergent technologies in creative work, and help the sector to identify and isolate high emissions areas and develop interventions. Transparent data reporting will foster accountability, ensure regulatory compliance, and encourage widespread adoption of sustainable practices.

3. Integrated solutions

Reducing the negative sustainability impacts of convergent technologies in the Creative Industries requires integrated solutions that address energy consumption, resource management, and waste across the entire production lifecycle. Key strategies include the widespread adoption of energy-efficient technologies (like cloud computing powered by renewables), transitioning to circular economy models (for devices and physical assets), and promoting collaboration and upskilling across industries. A combination of technological innovation, policy frameworks, and sustainability-driven decision-making will be essential for guiding the Creative Industries toward a just and green transition.



Introduction

Scene setting

Can the UK Creative Industries harness the creative and entertainment potential of convergent technologies without compromising the planet? Can the Creative Industries help drive sustainable outcomes by planning for the widespread adoption of these technologies?

These questions serve to catalyse this report. They inform Arup's research and analysis of the ways in which convergent technologies such as artificial intelligence (AI), virtual reality (VR), and virtual production (VP) may change the operational models of the Creative Industries, and what these changes may mean in terms of environmental impact.

AI-enabled tools, for example, can produce text, sounds and images in seconds and minutes, rather than the hours, days and weeks it may take a human (see loudly.com; Mirowski 2023). VR and 'metaverse' experiences can dramatically alter how concerts and films are experienced, creating fully interactive worlds of entertainment accessible from home. Immersive technologies can enhance real-world experiences, from interactive exhibitions in museums to augmented theatrical productions, adding layers of engagement and personalisation without the need for custom-built physical objects. VP techniques, combining real-time rendering and advanced graphics, are enabling creators to build or recreate hyper-realistic environments, minimising the need for travel or the construction of physical sets.

The environmental impacts of these developments may appear, at first glance, to be positive. VP, for example, may reduce the need for travel and on-location filming, thus cutting fuel use, while virtual sets may reduce the need for single-use materials, thus cutting waste. Changes such as these may be welcomed by the Creative Industries as they look to make productions more sustainable (informed by reports such as the Screen New Deal (Albert 2020) and its associated Transformation Plan for Wales (Arup 2023)). But there are negative impacts to consider, too. A greater reliance on digital and cloud technologies means increased demand for energy-intensive data centres that require vast amounts of water to cool. New hardware for new forms of content production and consumption will, at the end of its useful life, contribute to the world's mounting e-waste problem without considered management.

With the Creative Industries subject to the twin pressures of the drive to innovate and to operate more sustainably, there is an urgent need to support the sector to make an assessment of the environmental impacts of convergent technologies, and to properly factor those assessments into their sustainability strategies and action plans. Assessments may be challenged, though, by the absence or patchy nature of data necessary for evaluating the sustainability credentials of emerging and nascent technologies. Even when technologies are more established and data more readily available, longer-term impacts may have yet to materialise or be fully captured in available data. Without concerted efforts to obtain and analyse necessary data, the Creative Industries risk fast-tracking technologies that may be innovative, sophisticated and efficient in terms of production, but which create more waste, emit more carbon and divert the sector from practices that would otherwise lead to a more sustainable future.

Project method

The research approach for this report utilised both qualitative and quantitative methods (Figure 1). A horizon scan was conducted to identify future risks, opportunities and trends that may impact the Creative Industries, taking technological, social and economic perspectives into account. Emerging technology trends were identified, following which a sustainability analysis was conducted and workshopped to yield four future sustainability impact areas that span various convergent technologies: VP, generative AI, hardware and wearables, and virtual existence. Exploration of these areas provided three cross-cutting themes that are critical to sustainable progress: directive industry leadership, data acquisition and reporting, and integrated solutions.

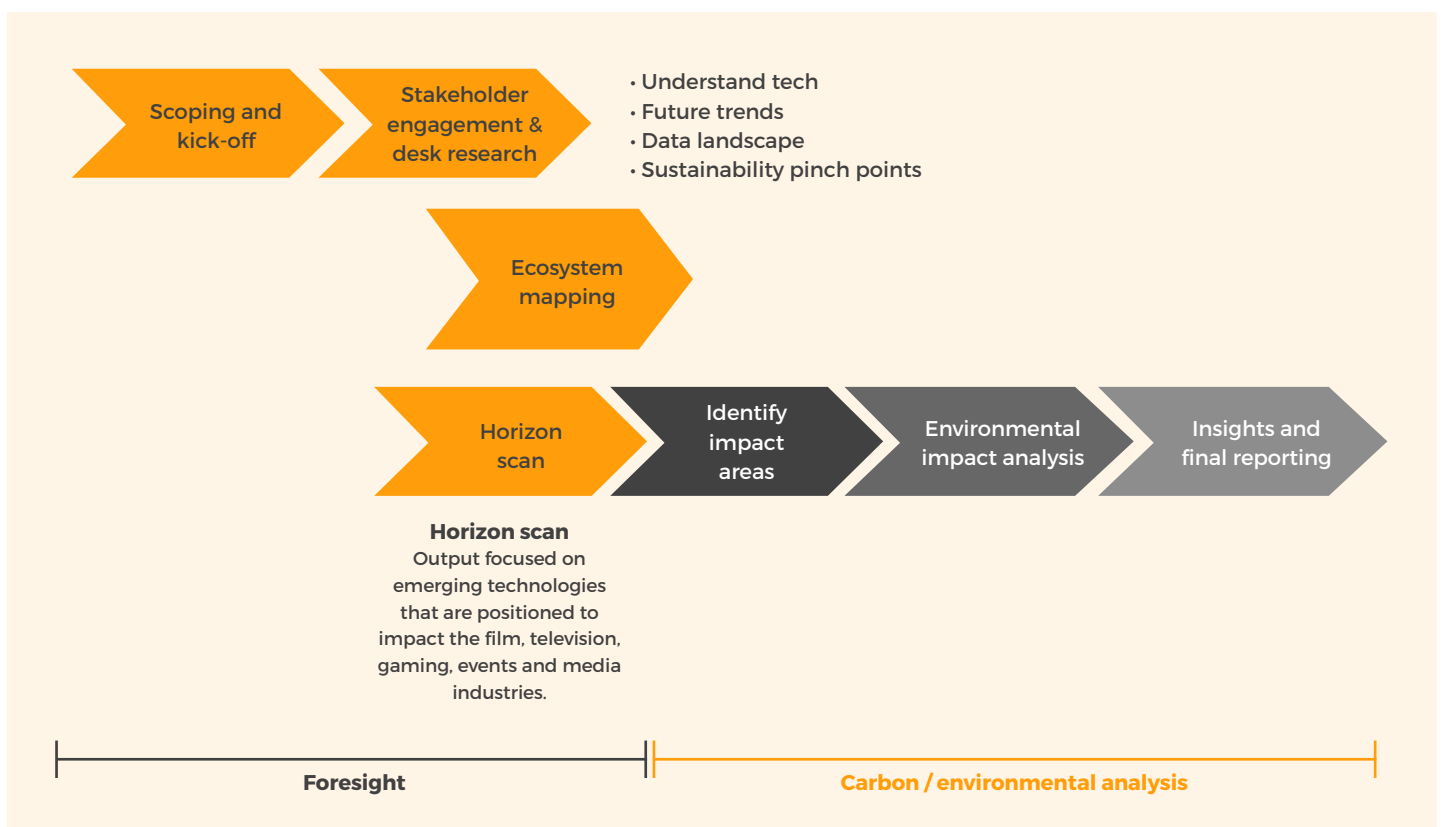


Figure 1: Visual overview of the project method.

Report structure

The next section of this report explores the four **future sustainability impact areas**. These areas were distilled down from a wide-reaching horizon scan, due to their carbon impact and significance when examining the wider sector. For each of these areas, the report summarises positive and negative sustainability impacts; case studies and examples of sustainable development; actions; identified research gaps; and recommendations linked to the report's three cross-cutting themes.

A sustainable future for the Creative Industries draws those thematic recommendations together for a summary of implications and next steps. Finally, the **Appendices** contain further details on research methodology (Appendix A), emerging technology themes identified through research (Appendix B), and carbon analyses of technologies seen as most transformative for the future of the Creative Industries (Appendix C).

Future sustainability impact areas

Virtual production: More sustainable than traditional methods?

Virtual production (VP) is becoming an increasingly mainstream method of content creation (Windsor 2025), providing novel creative opportunities across film and television, gaming, advertising and live broadcast. VP practitioners have claimed that, alongside creative benefits, the technology delivers environmental benefits. A report from Studio Ulster highlights that VP can reduce carbon emissions by up to 50%, depending on how it is deployed (Keeney 2023). This reduction is primarily due to decreased travel and on-site fuel consumption, which currently account for a substantial portion of the screen sector's carbon footprint. Additionally, CGI Backgrounds reports that fully virtual productions can reduce emissions by up to 95% compared to traditional on-location shoots (Cumming 2023).

While the existing evidence base is valuable, there are potential gaps that require further investigation. First, productions commonly use a combination of traditional and VP-based methods, creating a complex value chain that is challenging to model accurately to quantify associated emissions. Second, there are aspects of VP processes where data is lacking – specifically, data on power requirements for processing and storage of content, and wider supply chain and end-of-life data for LED screens and other parts of the VP technology stack.

How does virtual production contribute to, or challenge, sustainable progress?

Carbon emissions and sustainability impacts associated with VP processes (Keeney 2023) include:

1. Power consumption: High power consumption is caused by high-performance computing, large LED volumes and real-time rendering.

Key question: *Does the power consumption associated with total, or partial, use of VP result in increased carbon footprint, or would emissions be reduced, compared to shooting equivalent scenes on location, if VP energy supply was decarbonised?*

2. Heat emissions and cooling needs: High-performance computing generates significant heat, requiring extensive cooling systems, which further increase energy consumption.

Key question: *How can we minimise heat creation associated with VP and therefore limit the need for extensive cooling systems that are energy intensive?*

3. Hardware manufacturing and disposal: Demand for VP increases the manufacture and procurement of high-spec equipment.

Key question: *Can we quantify and manage the emissions associated with the manufacture, use and disposal of LED panels and other equipment, proactively seeking to reuse whole assets or components and reintroduce them back into the value chain?*

How do we sustainably develop this area?

Calculating and reporting of emissions is a complex technical exercise which is only just beginning to work comprehensively for traditional production methods. The Creative Industries have not yet been able to robustly quantify emissions associated with new VP processes, and this presents an additional challenge when trying to understand whether VP reduces environmental impact compared to traditional methods.

For guidance, the Creative Industries could look to other sectors such as construction, finance and manufacturing, which have developed rigorous carbon accounting frameworks to accurately quantify emissions. Sectors such as construction and manufacturing use lifecycle assessments (LCA) and scope 1-3 emissions tracking to measure environmental impact. Scope 1-3 emissions are defined by the Greenhouse Gas Protocol and provide a greenhouse gas accounting classification system, where scope 1 covers direct emissions from owned or controlled sources, scope 2 covers indirect emissions from purchased electricity, and scope 3 covers indirect emissions across the value chain (ghgprotocol.org). Similar models could be applied to VP, perhaps with the support and collaboration of sustainability experts from these sectors (see Table 1).

Sector	Focus of environmental reporting	Relevance to the Creative Industries
Financial institutions and ESG (environmental, social and governance) investors	<p>Carbon reporting focuses on tracking emissions associated with investments, loans and other financial activities, using frameworks such as the Greenhouse Gas Protocol and the Partnership for Carbon Accounting Financials. It typically applies a financed emissions approach, where emissions are allocated to financial institutions based on their share of investment in a company or project.</p> <p>Methods include spend-based estimates, using sector-level emission factors, and more precise activity-based calculations, relying on reported emissions from financed entities. As data quality improves, financial institutions increasingly shift toward direct reporting and engagement with clients to drive emissions reductions across their portfolios.</p>	Low
Manufacturing and construction	<p>Carbon reporting tracks emissions across operations, supply chains, and product lifecycles using a mix of activity-based and spend-based methods.</p> <p>Activity-based calculations rely on direct data, such as energy use, material inputs, and process emissions, providing precise results, especially when combined with LCA and Environmental Product Declarations (EPD). Spend-based methods, which estimate emissions based on financial expenditure and industry-average factors, are used when direct data is unavailable.</p> <p>Many manufacturers integrate both approaches, refining estimates over time to improve accuracy, meet regulatory requirements, and drive sustainability improvements.</p>	High – the Creative Industries should utilise this hybrid model of spend-based and activity-based methods to create a comprehensive footprint for each production.

Table 1. Sector-specific approaches to environmental reporting.

In the construction industry, measuring emissions across a product’s whole lifecycle follows the A to D framework:

- **Stage A** (product and construction stages) includes raw material extraction (A1), transport to manufacturing (A2), production (A3), transport to site (A4), and construction/installation (A5).
- **Stage B** (use stage) covers emissions from maintenance, repair, replacement, and operational energy use.
- **Stage C** (end-of-life stage) accounts for deconstruction (C1), transport of waste (C2), processing (C3), and disposal (C4).
- **Stage D** (beyond system boundary) considers potential benefits from reuse, recycling, or energy recovery.

This full-cycle approach ensures a comprehensive view of environmental impact, and is shown in Figure 2.

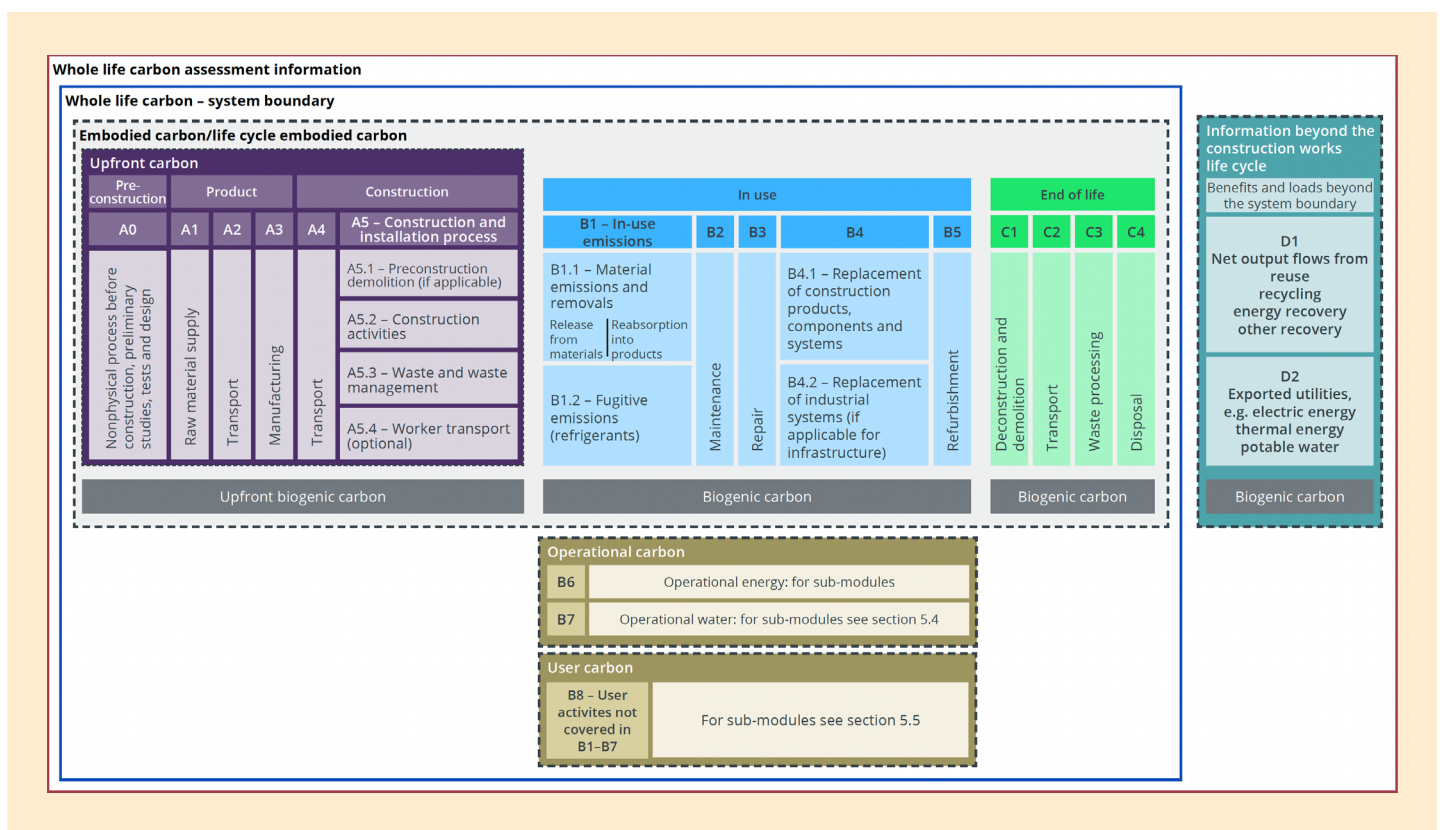


Figure 2: RICS lifecycle assessment modules, published as Figure 11 in RICS (2024).

Considering the A to D framework in the context of VP helps to flag parts of the process that are not currently being assessed for carbon impact. For example, the embodied carbon of the equipment required for VP, as well as supply chains and end-of-life emissions for LED walls and other equipment. In some cases, equipment might be reused and its life extended through proactive maintenance; otherwise it means a much higher amount of e-waste being created and entering landfill. If equipment or components are captured and reused, however, this affects the emissions associated with the use of these technologies. It is therefore a priority for the sector to develop an emissions framework that provides evidence to help creative businesses and creative workers make informed decisions and decarbonise their work.

Sector stakeholders, including producers, crew and technicians, also need to be equipped with evidence and actions to enable them to manage and mitigate the energy demands associated with computer processing, rendering and storage. Equipment needs to be efficient and not use unnecessary amounts of power. Data centres that are now a significant part of the VP value chain need to be operated in an efficient manner and be powered by renewable energy sources. Areas for change could include:

- **Energy efficiency:** Use advanced cooling techniques (e.g. liquid cooling, free cooling) and optimise server utilisation.
- **Renewable energy:** Power operations with solar, wind, or hydro energy sources.
- **Waste heat recovery:** Redirect excess heat to nearby buildings or district heating systems.
- **Efficient hardware:** Deploy energy-efficient servers, processors, and storage solutions.
- **AI and automation:** Use AI to optimise cooling, workload distribution, and energy consumption.
- **Water conservation:** Implement closed-loop or evaporative cooling to reduce water use.
- **Circular economy:** Reuse, refurbish, and recycle IT equipment to minimise e-waste.
- **Carbon offsetting:** Invest in carbon credits or support reforestation projects.
- **Modular and edge computing:** Reduce energy demand by processing data closer to users.
- **Green building design:** Construct data centres with sustainable materials and smart energy management systems.

Table 2 consolidates these decarbonisation actions, as well as data reporting approaches, for each lifecycle stage of virtual production, with a particular focus on VP hardware.

Lifecycle stage	Product (A1-A3)	Construction (A4-A5)	Use (B1-A7)	End-of-life (C1-C4)	Reuse and recovery (D1-D2)
Virtual production activity	Development	Pre-production	Production	Post-production	Post-production/ Development of next production
Decarbonisation actions	<p>Work with VP vendors and partners committed to carbon reduction and sustainable practices.</p> <p>Develop a sustainable sourcing plan for the production.</p>	<p>Select low carbon, recycled, or repurposed materials for physical assets like LED panels and set pieces.</p> <p>Maintain and upgrade existing hardware instead of replacing it, reducing electronic waste.</p>	<p>Use renewable energy to power VP stages, LED walls, and computing systems.</p> <p>Reduce rendering time and computational loads through efficient asset management and real-time rendering techniques.</p> <p>Track and report carbon emissions during production, adjusting strategies as needed to stay on target.</p>	<p>Donate, resell, or repurpose LED panels, servers, and other hardware to extend their lifecycle.</p> <p>Partner with certified e-waste recycling programs to ensure proper disposal of outdated technology.</p> <p>Store and reuse digital assets, 3D models, and environments to reduce future production demands.</p>	<p>Implement take-back schemes for hardware manufacturers to refurbish and reintegrate materials into new products.</p> <p>Reuse and share virtual assets, environments, and digital sets across multiple productions to reduce new resource demands.</p> <p>Share best practices and sustainability innovations with the sector to drive collective carbon reduction.</p>
Reporting methods	Account for emissions from the procurement of VP tech, using industry-average emissions factors linked to financial expenditures.	Use activity-based data to quantify travel and transportation emissions, as well as energy use, using energy mix (renewable vs. non-renewable) and energy consumption data.	Use activity-based data to quantify operational emissions – mainly energy use, using energy mix (renewable vs. non-renewable) and energy consumption data.	Use activity-based data to calculate emissions associated with the disposal, recycling, or repurposing of VP equipment (e.g. LED panels, servers, cameras). This includes emissions from transportation to waste facilities and energy used in recycling and disposal processes. Use e-waste recycling emissions factors to estimate these emissions.	Estimate emissions savings (or potential emissions) from reusing digital assets (e.g. 3D models, environments) in future projects instead of creating new ones. This can be done by considering the energy saved in future productions by avoiding the need for new rendering or modelling processes.

Table 2. Virtual production lifecycle with decarbonisation and reporting approaches.

Key themes

Leadership: Sector bodies, ranging from BAFTA albert to the Sustainable Entertainment Alliance to the CoSTAR Network, have the ability to influence and incentivise emissions reporting for productions using VP. Funding needs to be provided for pilot projects which focus on the development of tools which quantify emissions related to VP. This will provide evidence to certify whether VP results in reduced emissions for the Creative Industries.

Data acquisition and reporting: Accurate accounting methodologies need to be developed and published so productions are empowered and incentivised to measure emissions independently.

Integrated solutions: Investment and support is needed for sustainability innovation in VP. This relates to improving technology to ensure efficient and effective energy use. In addition, further innovation efforts relating to sustainability are required across UK data centre capability. This will include engagement with other sectors to integrate technology solutions into the operations of the Creative Industries. There are some initial solutions around heat capture from cloud computing (see, for example, heata.co) which involve installing servers directly into people's homes and utilising excess heat to warm domestic water tanks. However, these solutions are currently better suited to overnight or offline rendering tasks, as latency from distributed servers cannot support the real-time rendering needs of VP.

Actions and research gaps

Effort		Timeframe	
Low	Current systems are sufficient to achieve action without significant investment and change.	Short term	1-2 years
Medium	Requires a change in current ways of working and potential investment in new infrastructure and systems.	Mid term	2-5 years
High	Longer term action that requires significant time and resources and a fundamental shift in ways of working.	Long term	5-10 years

Table 3. Definitions for Actions tables.

Category	Action	Effort	Timeframe
Energy efficiency	Energy-efficient hardware: Use energy-efficient servers, GPUs, and other hardware that consume less power.	Low	Short term
	Renewable energy sources: Power data centres and production facilities with renewable energy sources such as solar, wind, or hydroelectric power.	Low	Short term
	Energy management systems: Implement energy management systems to monitor and optimise energy use in real-time.	Medium	Short term
Data management	Efficient data management: Implement efficient data storage and management practices to reduce unnecessary data duplication and storage needs.	Medium	Mid term
Material use	Digital asset reuse: Reuse digital assets and virtual sets across different projects to reduce the need for creating new ones.	Medium	Short term
	Material efficiency: For physical components, use sustainable materials and recycle or repurpose materials wherever possible.	Medium	Short term
Optimise cloud computing	Cloud computing: Leverage cloud computing resources that are managed for sustainability, as major cloud providers often use renewable energy and have efficient resource management practices.	Medium	Mid term
	Efficient rendering solutions: Use rendering solutions that are optimised for energy efficiency.	High	Long term
Model VP in carbon calculators	Integrate into existing film production carbon calculators: Starting with established models then factoring in the nuances of VP.	High	Mid term
	Supplement with IT carbon calculators: Given heavy reliance in VP, use IT-focused carbon calculators to estimate the emissions from data centres, cloud services, and the manufacture, use and disposal of technology.	High	Mid term
Skills and adoption	Engage experts and continuous learning: As an emerging field, VP needs to collaborate with sustainability experts and build awareness among professionals to fully unlock the green potential on offer.	Medium	Short term
	Advocate and collaborate: Advocate for policy that will support dedicated carbon calculators and collaboration among studios, technology providers and sustainability experts to create more precise tools.	Medium	Short term

Table 4. Sustainability actions for virtual production.

Research gap	Issue
Carbon impact of AI-enabled post production for film and television	Virtual production is an emerging practice, and its environmental impacts are not yet fully understood. While it can reduce the need for transport and waste from props and other physical set elements, it uses carbon-intensive programs and hardware.
Carbon footprint of virtual production methods throughout film/television production process	

Table 5. Research gaps for virtual production.

What is the role of the Creative Industries in making AI more sustainable?

The Creative Industries are at an inflection point in their use of generative AI. “Generative” refers to the ability of an AI model to learn patterns in the data they are trained on and then create new work by attempting to replicate those patterns. Recent advances in generative AI models have led to the wide availability of tools that can produce text and audiovisual content. Google DeepMind’s digital tool MusicFX DJ, for example, enables users to generate music interactively, in real time, by mixing musical concepts as text prompts (Google DeepMind 2024). In video gaming, NVIDIA Research used a generative model trained on 50,000 *Pac-Man* “episodes” to create a functional version of the game that runs without an underlying game engine. The researchers speculate that this capability could be used by game developers “to automatically generate layouts for new game levels” (Salian 2020).

As per a McKinsey global survey in 2024, nearly two-thirds of respondents from the media and entertainment sector reported regularly using generative AI (McKinsey 2025). AI’s creative applications include: information analysis; content enhancement and post-production workflows; information extraction and enhancement; and data compression (Anantrasirichai 2022). It offers benefits such as timesaving, cost reduction, and the democratisation of creative tools. However, there are risks associated with the growing adoption of AI. Many of the tasks that AI tools are now able to perform – such as writing and creating images – are traditionally the domain of human creators, and so AI has the potential to encroach on the work of skilled and experienced creatives. AI technologies and associated infrastructure also pose new sustainability challenges. Power consumed by AI tools varies depending on the task; research shows that the generation of images can consume a thousand times more energy than text classification tasks (see Figure 3).

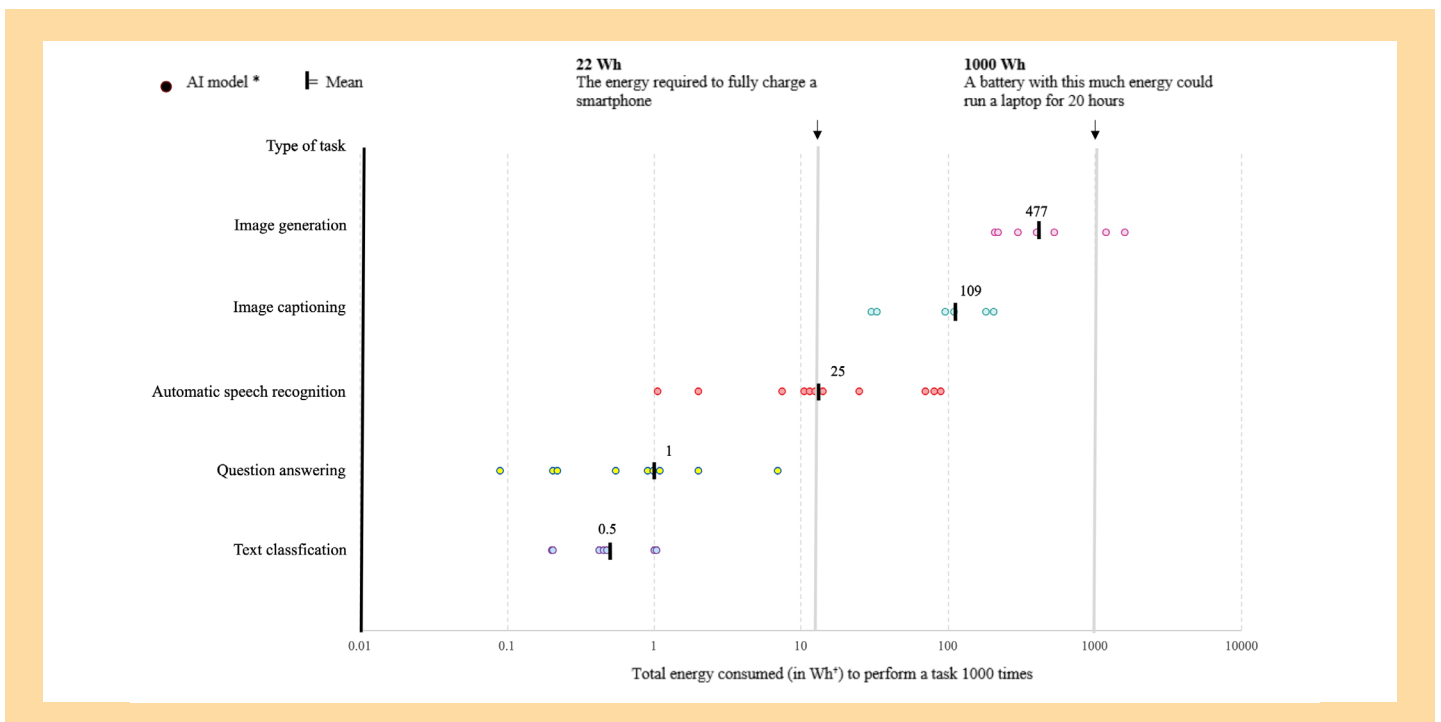


Figure 3: AI’s energy footprint, adapted from Luccioni and Gamazaychikov (2024). *Tests conducted on 20 popular open-source models. Each dot represents one model. *Watt-hour represents power consumption of 1 W extended over one hour.

Over the long term, AI's applications in the Creative Industries will likely be substantial (see Figure 4 and Jeary 2024). Post-production workflows could see increased use of AI, including enhanced tools for denoising, colourisation, segmentation, rendering and tracking. Motion and volumetric capture methods could benefit from enhanced parameter selection and rendering tools. Virtual production methods and games technologies will see greater convergence and increased reliance on AI methodologies. Given the Creative Industries' high levels of digitalisation, and the potential for recent generative AI developments to affect creative supply chains, the sector is poised to take a leading role in driving more sustainable thinking around the application of AI. Acknowledging both the positive and negative impacts of AI is important as the Creative Industries prepare to make investment and strategic decisions about these technologies, before getting "locked in" to unsustainable practices.

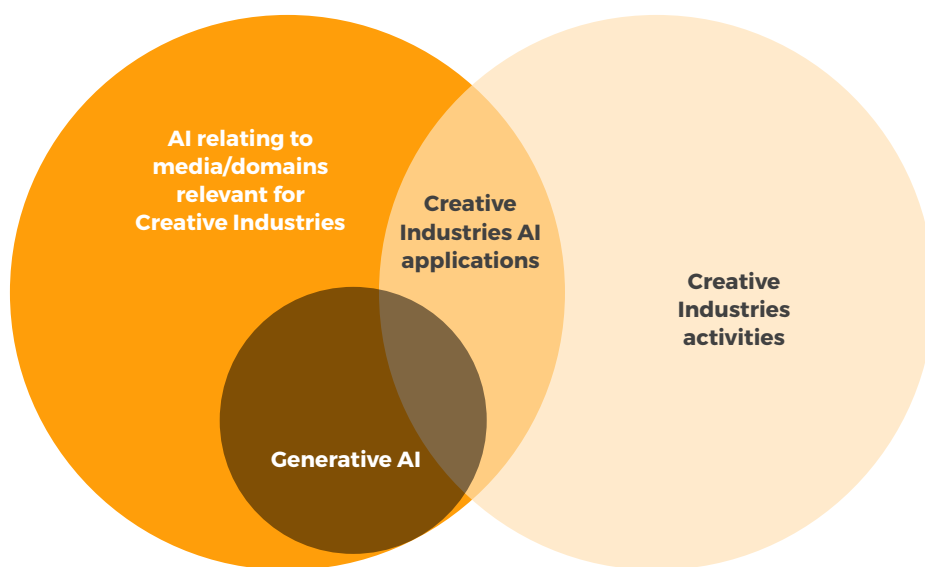


Figure 4: AI and Creative Industries activities and applications. Adapted from Davies (2020) under CC BY-NC-SA.

How does generative AI contribute to, or challenge, sustainable progress?

The most common generative AI models are text-to-text (e.g. ChatGPT), text-to-image (e.g. DALL-E and Midjourney), image-to-image (e.g. Lensa and Remini), and text-to-audio (e.g. AudioCraft). In addition, tools offering virtual actors and voice synthesis are being adopted by video game producers and by short-form creators who distribute their work on TikTok and YouTube (Davenport 2023).

Sustainability impacts associated with generative AI include:

1. Carbon footprint: According to Stanford University's Artificial Intelligence Index, the training of the GPT-3 language model by OpenAI in 2022 generated the equivalent of 455 tonnes of carbon dioxide emissions and almost 1,300 megawatt hours of power (hai.stanford.edu/ai-index). This is the equivalent of the lifetime emissions of eight cars – or the yearly emissions of 109 cars. The calculation to estimate tonnage of carbon emissions does not account for “emissions associated with the computers manufactured for the model's training, emissions from OpenAI's newly released GPT-4, or, crucially, the tech sector's plans to begin massively scaling up the use of language models and other AI technologies” (Zhang 2023).

2. Water footprint: Clean freshwater as a resource is extremely limited and unevenly distributed across the globe. AI models consume many millions of litres of freshwater for electricity generation and for cooling servers, and some of these servers will be deployed in regions where water is scarce, further exacerbating the problem. Researchers expect AI water requirements to increase with newer models relying on larger sets of parameters than their predecessors (DeGeurin 2023). By one estimate, the combined scope 1 and scope 2 operational water withdrawal of global AI may reach 4.2 billion to 6.6 billion cubic meters in 2027, which is more than half of the United Kingdom's total annual water withdrawal (Li 2025).

3. Consumer demand: An increase in the efficiency of AI technology is leading to an increase in the demand for AI-produced goods and services, further increasing resource use and pollution via rebound effects. The broadening of use cases for AI, and the proliferation of ways that AI could impact each use case (e.g. ubiquitous personalisation of content) could lead to potentially far greater demand for energy and water than occurs at present. For example, “as chatbots and image generators become more popular, and as Google and Microsoft incorporate AI language models into their search engines, the number of queries they receive each day could grow exponentially” (Saenko 2023). The International Energy Agency estimates that a single Google search uses 0.3 watt-hours of electricity, while a ChatGPT query consumes 2.9 watt-hours (for comparison, an average incandescent bulb uses 60 watt-hours). If ChatGPT were incorporated into the 9 billion daily internet searches, it would increase electricity demand by 10 terawatt-hours annually – equivalent to the consumption of approximately 1.5 million European Union residents (Calvert 2024).

Beyond generative models specifically, AI does have the potential to improve sustainability through, for example:

- **Energy efficiency and carbon reduction:** AI streamlines workflows, reducing computing power and energy usage in digital content production.
- **Enabling circular economy practices:** AI-powered tools improve predictive demand forecasting, reducing overproduction and waste.
- **Sustainable creativity and accessibility:** AI democratises creative tools, enabling individuals and small businesses to create high-quality content with fewer resources. AI-assisted content translation and adaptation make sustainable messaging more accessible worldwide.

How do we sustainably develop this area?

Figure 5 highlights the main factors influencing electricity consumption and greenhouse gas (GHG) emissions throughout the AI lifecycle. First, at the grid level, emissions depend on the location of the training servers and the energy sources powering the data centres. Second is length of the training procedures (size of the training dataset; number of times the model is executed; and the number of hyperparameter experiments used). Third is the rate and extent of end-user demand growth for AI-driven products – and this remains a key uncertainty. The total energy and emissions costs of AI increase sharply with each of these quantities (Dhar 2020). All this makes AI a uniquely challenging technology – one that requires clear leadership, data strategies and stakeholder collaboration across value chains to develop sustainably.

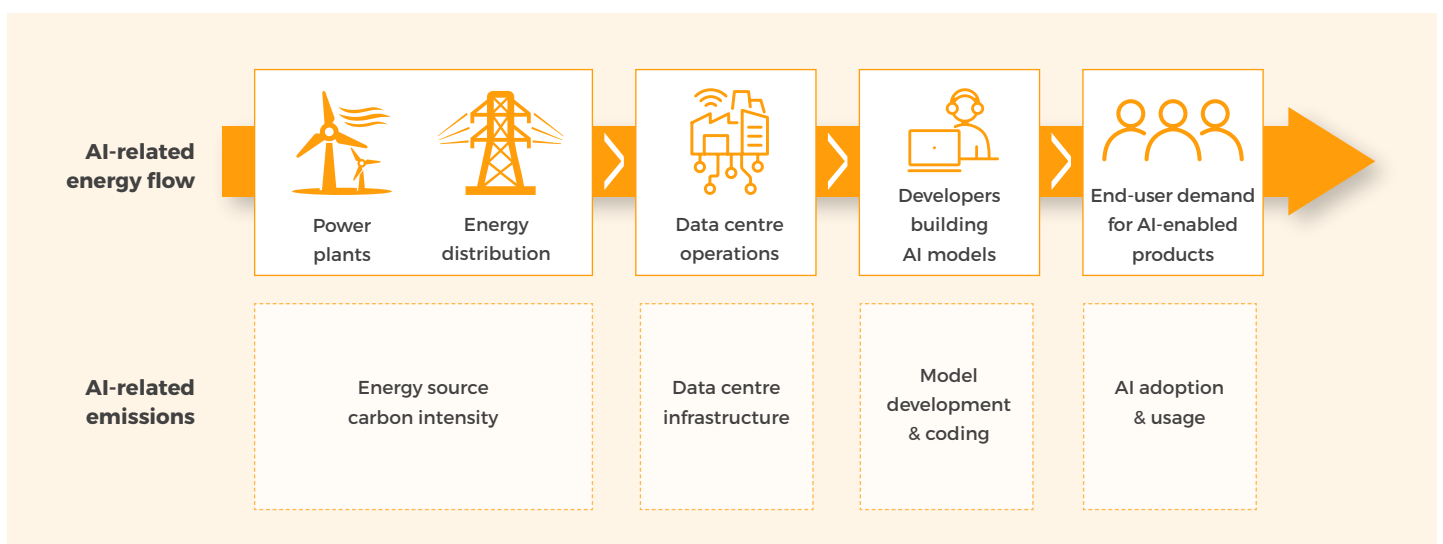


Figure 5: Critical factors determining AI's emissions footprint. Adapted from Dannouni (2023).

Key themes

Leadership: Big Tech has led the world in adopting renewable energy power purchase agreements. Google plans to operate all their data centres using carbon-free energy by 2030 and Microsoft has a target for data centres to be carbon-negative by 2030 (Harkness 2023). However, the explosive growth of AI saw both companies report higher GHG emissions in 2023 than in recent previous years (Rahman-Jones 2024; Ranger 2024). AI is expected to result in data centres using 4.5% of global energy generation by 2030 (Milmo 2024). It is challenging to estimate what proportion of this may be generated by the UK Creative Industries' use of AI. Regardless, the sector should look to set procurement standards and harness its purchasing power to demand energy-efficient AI models.

Data acquisition and reporting: The infrastructure of AI – and information about its environmental impacts – may be hidden or obscured from end users in the Creative Industries. Closing this data gap is essential. From a policy perspective, the European Union (EU) has provided a head start. The EU AI Act establishes a framework for developing harmonised standards aimed at improving AI systems' resource performance, with a particular focus on energy efficiency (European Union 2024). It also attempts to establish rules to monitor the energy performance of data centres, including energy and water footprint (Green Software Foundation 2024). These policy interventions provide a solid foundation for data tracking and monitoring – other countries should follow suit. Government-led mandates and specific environmental regulations will encourage model developers to consider energy use as an important parameter, resulting in a sector-wide reduction in GHG and scope 3 emissions for AI users in the Creative Industries (Appelle 2023).

Integrated solutions: Meaningful progress requires all stakeholders to take proactive steps to ensure the sustainable growth of AI, not just those in the Creative Industries. AI researchers and developers are at the core of innovation in this field and can significantly reduce AI's environmental impact by considering sustainability throughout the AI development and deployment stages. Actors across the AI value chain (data centre operators, AI developers, semiconductor manufacturers, end users) need to take a socially responsible approach and explore how individual movements and efforts can bolster support for AI that is more environmentally sustainable.

Actions

To reduce the environmental impacts associated with the growing use of AI in the Creative Industries, interventions must target the source. Organisations and AI users in the sector can influence AI model developers and service providers by advocating for greater transparency, adopting sustainable practices, and prioritising eco-friendly model development. Bridging the gap between AI developers and users would empower the Creative Industries to make informed, sustainable decisions. This approach could ultimately transform the sector and set a benchmark for responsible AI usage within the Creative Industries.

Action	Description
Promote transparency by disclosing energy and water consumption	AI users play a key role here. Favouring energy-efficient solutions can send a strong market signal, pushing developers and businesses to prioritise sustainability. By choosing models that transparently share energy and water usage data, and using AI products responsibly – for example, by avoiding unnecessary or wasteful applications – the Creative Industries can champion the cause, demonstrate leadership and guide the world towards more sustainable practices (Julie’s Bicycle 2021).
Strengthen regulation and governance	Policymakers want to encourage use of AI while mitigating risks. They have the authority to treat sustainability as a mandatory criterion in AI development and deployment. Policy frameworks that encourage energy or fuel efficiency in other economic sectors can be modified and applied to AI-powered applications. Efforts to monitor and benchmark AI’s energy requirements – and the associated carbon emissions – would help establish a mandate for firms using and deploying AI models to users in the Creative Industries.
Develop green AI certifications	Environmental standards should be developed to ensure the mitigation of environmental impacts, and green AI certifications could be introduced to facilitate processes for promoting green AI development. If key players (such as Google or NVIDIA) developed or adopted a sustainability certification process, it could be used as a standard across the field (Appelle 2023).
Use clean energy for training models	Using renewable energy grids for training neural networks is one of the single biggest changes that can be made. Emissions vary by a factor of 40 between a fully renewable grid and a fully coal-powered grid (Dhar 2020).
Recognise the importance of “when” and “where”	There may be opportunities to reduce the overall carbon footprint of AI models by running them in areas where the power grid consists of more renewable sources (Heikkilä 2023). It is also possible to exploit the spatial-temporal diversity of water efficiency to dynamically schedule AI model training and inference to cut down on AI water usage (Li 2025).
Minimise computational costs	Accenture (2023) suggests that companies “develop or adopt an accurate energy estimation approach that is non-invasive, vendor-agnostic and has comprehensive hardware coverage. This can help reduce the time and energy required for training and deployment, resulting in reduced emissions and costs”.
Adapt pre-trained models	Accenture (2023) also suggests that, where possible, businesses “fine-tune pre-trained large models for private use at a fraction of the cost and emissions required to build a new model. By reducing the size and complexity of these models, companies can shrink their energy consumption and carbon footprint”.
Make data centres more efficient	At an industry level, tackling AI emissions will, in part, require more efficient data centres, calculated using power usage effectiveness. Measures could include shifting servers to a low-power state where possible (Ranger 2024).

Table 6. Sustainability actions for AI.

Research gaps

Research gap	Issue
Carbon cost of AI technology as it continues to advance and become accessible to individuals.	Both training and operating AI models produces carbon emissions, and this will only increase as AI functions continue to be built into work and creative platforms. An uptick in AI-enabled content creation could see emissions rise dramatically, with users unaware.

Table 7. Research gaps for AI.

Case studies

- Researchers from Google and University of California, Berkeley have shown that the carbon footprint of large language models can be reduced by 100-1,000 times with the appropriate choice of algorithms, customised hardware and energy-efficient cloud data centres (Patterson 2021). For example, “the open-access BLOOM model, developed by the BigScience project in France, is similar in size to GPT-3 but has a much lower carbon footprint, consuming 433 MWh of electricity in generating 30 tons [27 tonnes]” of CO₂ equivalent (CO₂e; Saenko 2023).
- “Stability AI has launched its open-source StabilityLM suite of language models that can generate text and code and can be freely adapted for commercial and research purposes. One experiment by Accenture shows that training a much smaller “student” model, just 6% in size of the original “teacher” model, achieved the same level of accuracy (99%) but consumed 2.7 times less energy” (Accenture 2023).
- “CodeCarbon automatically captures the information needed to estimate CO₂ emissions due to computing, enabling users to track, record, and visualize the emissions released in the course of every experiment and across multiple projects. It also provides visibility into the levers that developers can pull to reduce their footprint. This in turn allows them to design more frugal and more efficient algorithms, position their servers in locations where producing power generates the lowest level of emissions, and choose the most efficient hardware for their systems” (Degot 2021).
- The AI Energy Score Project, inspired by the US Environmental Protection Agency’s Energy Star ratings, aims to “develop a system for scoring AI model deployment that will guide users in choosing models (and ways to run them) for different tasks based on their energy efficiency and to analyze the effect of implementation choices on the downstream energy usage of different models” (Luccioni 2024). This can help developers and users of AI models to take energy consumption into account, nudging them to lower their carbon footprint and choose the most energy-efficient models for their use case.
- The European Code of Conduct for Data Centres, led by the European Commission’s Joint Research Centre, sets ambitious voluntary standards to promote energy efficiency in data centres, including recommendations on energy use, environmental metrics, and reporting (Joint Research Centre 2022). The Climate Neutral Data Centre Pact is a self-regulatory initiative that includes more than 100 data centre operators and trade associations and aims to make data centres in Europe climate neutral by 2030 ([climateneutraldatacentre.net](https://www.climateneutraldatacentre.net)).
- There are examples of data centre operators working to offset their water usage. Google, for instance, aims to replenish 120% of the freshwater it consumes annually by 2030 through efforts such as wetland restoration, rainwater harvesting, and land conservation (Dannoni 2023).

Towards more sustainable manufacturing, use and disposal of hardware and wearables

The rise of the smartphone in the mid-to-late 2000s triggered a period of device convergence, as technologies for telephone calls, emails, photos, gaming and music merged into a single product. Now, though, with the launch of virtual reality (VR) and mixed reality headsets, smartwatches, wireless earbuds, and tablets, we are seeing growth in the multi-device ecosystem. To mitigate negative impacts from multi-device use, conscious and informed decisions must be made around material choices, manufacturing processes, and end-of-life disposal. The principles of a circular economy can minimise the environmental impact of these devices, to ensure that hardware and wearables are managed responsibly through their lifecycle.

For many new or emerging technologies in the Creative Industries, hardware must be developed or upgraded in parallel. For example, the newest and most immersive versions of extended reality (XR) will require high-definition headsets or haptic suits that are yet to be commercially available. As these technologies continue to develop, it is expected that the volume of sold and discarded hardware and wearables will increase. By 2027, according to [Statista.com](https://www.statista.com), approximately 31 million VR and augmented reality headsets will be shipped worldwide – more than double the amount in 2024. Without clear strategies for the recycling, circular design, and responsible manufacturing of these hardware products, the environmental impact of this technological growth could be significant. Some progress has been made toward circularity in wearables, such as the VIVE XR Elite, which is designed with 77% recyclable materials and a detachable and replaceable battery to extend the product life (VIVE Team 2024). Generally, however, more research and collective industry action is required.

The hardware used for immersive experiences and technology-enhanced entertainment requires various materials such as silicon and precious metals. Rare earth elements (REE), which are required for LED lights and VR headsets, exist in low concentrations and are hard to separate from other elements in minerals. The mining of these REEs releases toxic chemicals and generates waste with significant negative environmental impacts in surrounding areas (Nayar 2021). For example, due to decreasing copper ore grades, total fuel consumption for copper mining in Chile has increased by 130% between 2001 and 2017 (Azadi 2020). Overall, the mining industry exhibits several carbon and environmental impacts associated with deforestation and social challenges linked to forced labour. These challenges may amplify with the growing demand for emerging hardware.

At present, there are already significant challenges to managing the e-waste circulating through global economies. According to the Global E-waste Monitor, only 22% of the 62 million tonnes of e-waste was recycled in 2022 (globalewaste.org). E-waste is exported from the Global North to the Global South, where large waste dumps have emerged that cause health and environmental issues. The largest e-waste dump, Agbogbloshie, in Ghana, receives around 227,000 tonnes of electronics and appliances a year (CBC Radio 2019). Informal backyard recyclers from marginalised communities, including women and children, traverse through these e-waste dumps to extract precious metals and valuable materials without protective equipment, exposing themselves to devastating effects of toxic heavy metals and poisonous gases generated through unregulated burning of waste. These substances are not only damaging to the environment, but have been known to cause adverse birth outcomes, neurocognitive issues, and decreased lung function (Harris 2022).

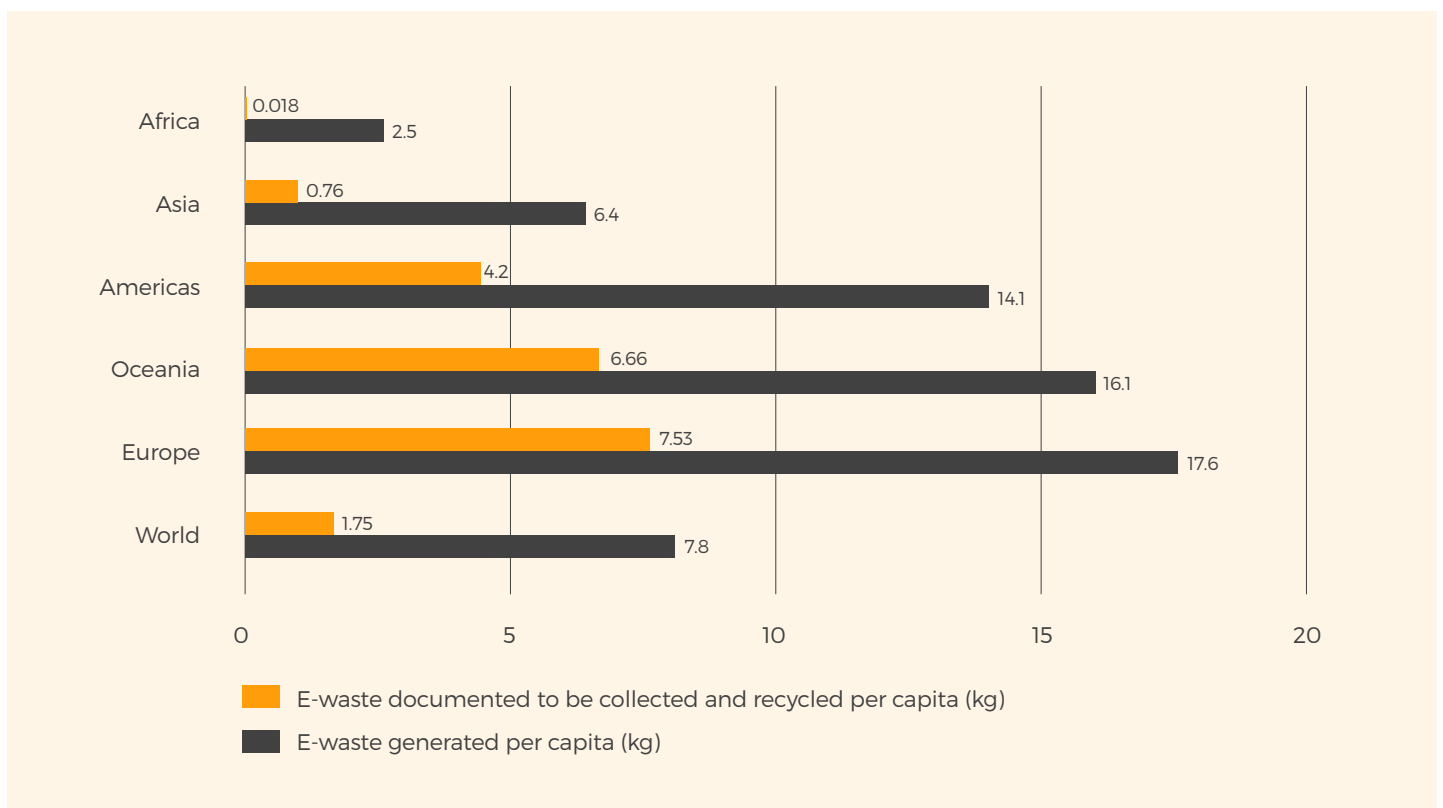


Figure 6. Global e-waste recycling rates. Adapted from The Global E-waste Monitor 2024 (globalewaste.org).

How do hardware and wearables contribute to, or challenge, sustainable progress?

Technologies such as AI, VR, and virtual production are transforming the Creative Industries, from film and television to theatre and live performance. As these technologies continue to evolve and gain traction, it is essential to examine the hardware components that enable them, and consider the broader sustainability implications of their production, use, and end-of-life.

Positive sustainability outcomes	Negative sustainability outcomes
<p>Hardware and wearables are intimately tied to the success of certain technologies within the entertainment and Creative Industries. For example:</p> <ul style="list-style-type: none"> • LED walls are an essential component to virtual production and can reduce the amount and number of people and goods needed to make a physical set for film, TV, and theatrical performances. • VR headsets and haptic suits enable the production and consumption of virtual experiences. Designing sets and attending concerts virtually will reduce physical waste associated with going to a live concert such stage and set materials (temporary installations), event infrastructure (banners, props) and on-site waste from food and beverages. 	<p>Globally, 62 million tonnes of e-waste were generated in 2022. Notably, less than a quarter of this generated waste was formally recycled to minimise environmental impacts. Electronic products are manufactured globally, but a relatively large proportion of e-waste is generated by usage in the Global North. For example, in 2022 the UK generated 24.5 kg of e-waste per capita compared to 1.2 kg per capita in Cameroon. A significant volume of e-waste, around 3.3 million tonnes, is shipped across borders to countries in the Global South, leading to environmental and health related issues (globalewaste.org).</p> <p>The combination of planned obsolescence and incremental technology upgrades leads to an increase in the overall resource and energy demand required to produce hardware. Another aspect which leads to resource demand is when e-products are proprietary and non-transferable across devices.</p>
<p>Proper recycling of precious metals and reusable materials will prevent unnecessary e-waste from accumulating and offsetting the potential reduction in physical waste and resource usage. In the UK, there are instances of companies building their own customer-facing waste management infrastructure, outside of the traditional public channels, to bridge the gap between initial product design and proper recycling. For example, electrical goods retailer Currys runs a facility dedicated to the recycling and repurposing of old electric goods (Butler 2024). The Creative Industries can leverage demand-side pressures on the manufacturers of emerging hardware to adopt similar approaches to waste management.</p>	<p>Improper recycling is a threat to public health and safety. For example, the open burning of e-waste releases lead into the environment which has implications for neurodevelopment (World Health Organization 2024).</p>
<p>In 2022, the value of precious raw materials in EU-based e-waste was estimated to be \$12.9 billion (Bel 2022). This can amount to a significant portion of income for backyard recyclers.</p>	<p>The prevalence of international e-waste policy, legislation or regulation is not accelerating in line with targets set by the International Telecommunication Union. As of June 2023, only 42% of countries have set relevant policy to manage and combat e-waste (globalewaste.org).</p>

Table 8. Positive and negative sustainability outcomes for hardware and wearables.

How do we sustainably develop this area?

Striking a balance between the sociocultural benefits enabled by hardware and wearables and their negative environmental impacts is a challenge. The most sustainable and least carbon-emitting option will always be to refrain from producing physical goods. However, this is not aligned with the concept of green growth, which the Organisation for Economic Co-operation and Development (OECD) defines as a strategy that provides a strong focus on fostering the necessary conditions for innovation, investment and competition but is also consistent with resilient ecosystems (OECD 2013).

Technologies and complementary hardware have the capacity to enhance the entertainment experience. To minimise the environmental impact and carbon footprint of these technologies, the Creative Industries must re-examine hardware production processes and adopt circular principles. A circular approach not only reduces the carbon impact of hardware but also encourages greater collaboration and transparency across the entire value chain of the Creative Industries. This shift in business model benefits not only the Creative Industries but also extends to upstream manufacturers and downstream consumers, ensuring that sustainability is embedded at every stage.

Circular economy principles

The 9R Framework is a circular economy approach that moves away from the traditional linear model of make-use-dispose to one where products are designed with end-of-life considerations (Malooly 2023). The Creative Industries should look to apply this framework to infuse circular principles into the design, production, usage, and disposal of hardware.

Category/ stage	Description	Applicability to the Creative Industries	Responsibility
Design and manufacture smarter	RO: Refuse Refusal of consumption may end certain production processes or enable the transition away from environmentally detrimental products in favour of sustainably manufactured alternatives.	<ul style="list-style-type: none"> Assess what types of hardware are essential to deploy. Encourage sustainable behaviour among the Creative Industries such that they refuse to adopt any hardware that is not sustainable or sustainably managed. Education and training among consumers may lead to the refusal of unsustainably produced hardware. This can include refusing to purchase frequently updated hardware releases to avoid waste. 	Hardware manufacturers; sector leaders; consumers
	RI: Rethink Rethink product use and increase utilisation of hardware by enabling a sharing model and promoting multi-functional products	<ul style="list-style-type: none"> Rethink how hardware is used in the Creative Industries by evaluating the processes of single-use or individually owned hardware (e.g. sharing economy). Consider how technological hardware can be used to reduce the demand for other physical products (in a positive sense). Rethink the model of production and consumption, implementing a circular business model, such as product-as-a-service (PaaS), which reimagines ownership and single-use consumption by focusing on shared access and longevity of products. 	Creative Industries; hardware manufacturers
	R2: Reduce Reduce material consumption through product design. Identify opportunities to reduce and design out waste across the whole product lifecycle. This includes the amount of packaging and surplus material in logistics.	<ul style="list-style-type: none"> Design out waste and materials from the onset of developing and manufacturing physical hardware for technologies. Whole life carbon assessments of hardware and wearables will enable the reduction of unnecessary waste by identifying hotspots. Utilise modular hardware design to enable the repurposing and remanufacturing of electronic parts. Avoid and counter planned obsolescence of hardware. 	Hardware manufacturers

Category/ stage	Description	Applicability to the Creative Industries	Responsibility	
Life extension strategies	R3: Reuse	Resell or reuse discarded items to reduce the amount of new material used in manufacturing.	<ul style="list-style-type: none"> Reuse of VR headsets, LED walls and other entertainment-related hardware and wearables. Devise collection schemes for hardware and wearables at events, or as a broader initiative. Create platforms for exchanging used hardware among sector players. 	Creative Industries professionals: event organisers, producers
	R4: Repair	Extend hardware and wearable lifespan through maintenance and repair.	<ul style="list-style-type: none"> Widely offer repair and maintenance for hardware and wearable devices. Leaders can mandate the inclusion of instructions to users (on the production and consumption side) on how to maintain hardware. Educate and communicate with consumers on available repair services, instilling a behaviour change that drives people to instinctively repair products first before discarding. 	Hardware manufacturers
	R5: Refurbish	Refurbish an old product to bring it up to date through upgrade or modernisation. Refurbishment can include internal or external components.	<ul style="list-style-type: none"> Prioritise refurbishment over new products by eliminating small incremental updates. Educate consumers about refurbishment. Ensure hardware remains compatible for its intended use. 	Hardware designers and manufacturers; sector players
	R6: Remanufacture	Remanufacture intact components from old products into new releases.	<ul style="list-style-type: none"> To avoid unnecessary e-waste, use waste from hardware at end-of-life to manufacture new products of the same function. Pair a return policy with discounted upgrades of hardware. Reuse materials such as plastic from headsets and other hardware. Develop knowledge and understanding of remanufacturing opportunities. 	Hardware manufacturers
	R7: Repurpose	Repurpose product components into new products with alternative functions.	<ul style="list-style-type: none"> Identify the key components in hardware and wearables that have repurposing potential. Create cross-industry alliances for repurposing electronic components and other materials. 	Hardware manufacturers
Creative material application	R8: Recycle	Recycle the components of products into secondary raw materials.	<ul style="list-style-type: none"> Identify guidelines and recover valuable materials and components from hardware and wearables. Integrate recycling services during entertainment production and events. Contribute to the improvement of working conditions of backyard recyclers. This may include creating partnerships for recyclers to sell hardware components that are contingent on healthy and safe working environments. 	Waste management services; Creative Industries professionals: event organisers, producers
	R9: Recover	Recover energy from waste	<ul style="list-style-type: none"> As a last resort, incinerate non-recyclable plastics or composite materials in waste-to-energy plants instead of disposing in landfill. Notably, not all hardware components are suitable to be disposed in waste-to-energy plants due to hazardous materials, however packing and associate materials could be suitable. 	Waste management services

Table 9. Applicability of the 9R Framework (Malooly 2023) to the Creative Industries.

Supply chain considerations

Supply chains generate a significant portion of emissions for most industries due to complex global logistics, raw material extraction, energy intensive production, limited use of clean technologies and outsourcing to reduce costs. Transitioning to sustainable supply chains is essential to ensure that the hardware compatible with Creative Industries technologies are low-carbon and minimise negative environmental impact.

Table 10 shows each of the 15 scope 3 GHG emissions categories ([ghgprotocol.org](https://www.ghgprotocol.org)) with potential implications for the Creative Industries.

GHG Protocol scope 3 category	Implications and considerations
Cat. 1 Purchased goods and services	AI and internet of things (IoT) technologies can optimise production processes that reduce energy and material use in manufacturing, leading to lower embodied carbon in purchased goods. Blockchain could enhance transparency across the value chain, enabling organisations to make low-carbon sourcing decisions.
Cat. 2 Capital goods	Digital twins and IoT can optimise the design, maintenance, and monitoring of capital goods, leading to enhanced energy efficiency.
Cat. 3 Fuel- and energy-related activities	Blockchain can enable renewable energy procurement to reduce category 3 emissions.
Cat. 4 Upstream transportation and distribution	AI can enable upstream route optimisation, reducing fuel consumption and associated emissions.
Cat. 5 Waste generated in operations	Additive manufacturing reduces waste by using exact materials in production.
Cat. 6 Business travel	Advancements in immersive and digital communication technologies may reduce the need for business travel. Travel choices can be optimised through AI.
Cat. 7 Employee commuting	Digital communication technologies present more opportunities for remote working, which reduces travel emissions.
Cat. 8 Upstream leased assets	AI, IoT, and other analytic technologies can lead to the optimisation of energy efficiency and consumption in upstream leased assets.
Cat. 9 Downstream transportation and distribution	AI can enable route optimisation for last-mile delivery logistics, reducing emissions.
Cat. 10 Processing of sold goods	Additive manufacturing allows for more efficient processing of products, using less energy and materials. Digital twins can simulate product lifecycles, improving efficiency and reducing emissions during processing.
Cat. 11 Use of sold products	Depending on an organisation's sold products, various emerging technologies can enhance energy efficiency and monitoring.
Cat. 12 End-of-life treatment of sold products	Blockchain enables transparency and can track the lifecycle of products to ensure proper disposal and/or reuse of materials. Additive manufacturing further reduces potential waste at end-of life.
Cat. 13 Downstream leased assets	AI, IoT, and other analytic technologies can lead to the optimisation of energy efficiency and consumption in downstream leased assets.
Cat. 14 Franchises	n/a
Cat. 15 Investments	Blockchain can enhance transparency in investment portfolios, ensuring that capital is directed towards low-carbon technologies. AI can optimise financial decision-making to favour sustainable investments.

Table 10. Implications and considerations for transitioning to a more sustainable hardware supply chain.

Key themes

Leadership: The Creative Industries must lead by putting demand-side pressures on the manufacturers of compatible hardware technologies to adopt circular business models and transition to low carbon materials in their products. Industry standards and commitments can drive change across the value chain.

Data acquisition and reporting: Collecting data on the manufacturing, use, and disposal of hardware is essential in creating a baseline for material use upon which the circular framework can be monitored.

Integrated solutions: Adopting a circular approach is beneficial to reducing the negative carbon impacts of physical hardware, but also has co-benefits in promoting collaboration and transparency along the entire value chain of the Creative Industries. Open innovation, knowledge sharing, and digitalisation of data on circular business models are key levers to promoting a green transition for not only the organisations within the Creative Industries, but for upstream manufacturers and downstream consumers.

Actions

Category	Action	Effort	Timeframe
Circular economy transition	Create a Creative Industries coalition of producers, product manufacturers and designers, and sustainability experts. This coalition will enable collaboration and knowledge transfer for a circular economy transition. The coalition objective should be to mitigate the impacts of emerging hardware.	Medium	Short term
	Implement circular economy principles (e.g. 9R framework) from the onset of hardware development.	High	Medium term
	Develop and share case studies of circular hardware. Best practices should be disseminated across the Creative Industries in a collaborative effort to eliminate waste and minimise the environmental impact of hardware.	Medium	Medium term
	Foster partnerships with research institutions and materials scientists to further advance the circular economy transition in the Creative Industries.	Low	Short term

Category	Action	Effort	Timeframe
Whole life carbon	Whole life carbon assessment (WLCA) requirements for hardware: Lobby industry regulators and government bodies to mandate WLCA assessments for hardware used in technologies such as VR.	High	Medium term
	Develop hardware-specific WLCA guidelines: Collaborate with stakeholders to develop WLCA frameworks specific to the hardware used in Creative Industries, ensuring they align with broader environmental standards.	High	Medium term
	Establish agreed material and energy efficiency benchmarks: Collaborate with manufacturers and engage stakeholders to establish benchmarks specifically for the Creative Industries.	Medium	Medium term
	Provide advice on supply chain engagement for conducting WLCA: Gather sector-wide insights and provide advice on supplier engagement, encourage suppliers to provide carbon data for the hardware products they sell, ensuring transparency and accountability across the supply chain.	Medium	Short term
	Conduct WLCA for emerging technologies: Evaluate the full lifecycle carbon impacts of new emerging technologies by commissioning independent WLCA assessments.	Medium	Short term
	Build a hardware-specific WLCA database: Compile data on the WLCA outcomes of hardware products used in the Creative Industries to ensure a transparent and comprehensive database for sector use.	High	Medium term
	Develop capacity around WLCA in the sector: Develop training sessions and materials that educate companies on the importance of WLCA in hardware procurement and the environmental benefits of choosing sustainable options.	Medium	Short term
Design and manufacturing	Transitioning to renewable energy: Set goals for all hardware manufacturers to transition to renewable energy (e.g. solar, wind) for their production facilities. Facilities can set near-, mid- and long-term goals, for example, 2030, 2040 and 2050.	High	Medium term
	Procurement contracts: Leverage procurement contracts to promote the use of renewable energy for hardware manufacturers.	Medium	Short term
	Modular hardware design: Educate on, and promote the use of, modular design principles in the Creative Industries to reduce lifetime embodied emissions of hardware (e.g. by introducing modular certification, incentivising the purchase of modular hardware).	Low	Medium term
	Mainstream eco-design guidelines for emerging hardware technologies: Form a working group with stakeholders to create detailed eco-design guidelines that prioritise energy efficiency, minimal material use, modularity, and recyclability in hardware.	High	Medium term
	Invest in the research and development (R&D) of sustainable materials and supply chains: Industry coalitions should commit a fixed proportion of revenue to R&D for sustainable materials (e.g. bioplastics, recycled metals) and production methods.	High	Long term

Category	Action	Effort	Timeframe
Lifecycle extension	Mandate the inclusion of end-of-life instructions in hardware manuals: To enable consumers to reuse, repurpose, or recycle hardware, detailed instructions for end-of-life treatment should be included in product manuals.	Medium	Short term
	Incentivise the return of used hardware: Extend the lifecycle of hardware through the use of signposting, monetary incentives, and take-back schemes.	Low	Short term
	Develop industry-specific guidelines on e-waste recycling to minimise the damage and pollution generated by e-waste disposal.	Low	Medium term
Education	Educate professionals and consumers on the environmental impacts of hardware: Educational programmes, infographics, and courses on embodied and operational carbon should be disseminated across the Creative Industries.	Medium	Short term

Table 11. Sustainability actions for hardware and wearables. See Table 3 for “effort” and “timeframe” definitions.

Research gaps

Research gap	Issue
Transparent carbon lifecycles for all leading VR and gaming consoles.	Many of these new technologies require complex physical equipment. The extraction of precious metals, and other materials, intensive manufacturing processes, mass-scale shipping and afterlife all contribute significantly to carbon emissions. Clarity around the carbon impact and upcycling opportunities of hardware must be factored into a sustainable path forward.
Impact of emerging technologies on decreasing emissions across supply chains.	Management and transparency of supply chains will be an important part of monitoring the carbon impact of emerging technologies. Materials passports and carbon passports can help hold companies responsible when it comes to sustainable manufacturing, as well as enable more informed decision-making for consumers.

Table 12. Research gaps for hardware and wearables.

Virtual existence: How can we measure and manage emissions as experiences move to the metaverse?

With the metaverse becoming increasingly popular, the possibilities for virtual experiences are expanding. Platforms such as *Roblox* and *The Sandbox* have begun to create a new genre of immersive human co-experiences (Baszucki 2022; Sia Partners 2022), where users are directly responsible for creating their own virtual worlds in which they can socialise and engage with others for entertainment.

Meanwhile, the virtual event space is piloting experiences that leverage gamification and other metaverse attributes. Eminem's concert in *Fortnite*, for example, combined a vocal performance with *Guitar Hero* gamification (Webster 2023), and Travis Scott used *Fortnite's* avatar functionalities to transform his virtual appearance according to the songs in his concert (BBC News 2020).

From a sustainability perspective, virtual events promise benefits in terms of reducing transport and travel emissions, use of physical materials, and physical waste. They do, however, require servers and data centres to run, and for people around the world to connect to those servers via their computers and games consoles – and all that energy use is likely to generate carbon emissions.

Virtual productions are also not always completely virtual. Three different approaches to virtual events are:

1. **Digital first**, where an entire event is created digitally for virtual consumption;
2. **Real production for digital experience**, where a physical experience, which is not an event in itself, is captured and packaged into a virtual experience; and
3. **Real production with added virtual immersive experiences**, such as livestreaming or digital overlay events.

Two of these three approaches are hybrid events, involving a blend of both the physical and virtual. Ensuring these sorts of events are produced sustainably will therefore require the Creative Industries to work in tandem with digital and technology stakeholders to drive low-carbon development, including improving the energy efficiency of data centres, streaming platforms, and blockchain systems that power virtual worlds. As virtual events become more popular, failure to decarbonise on the digital side may simply result in a shifting of the environmental burden away from the physical side, rather than any meaningful reduction in the overall environmental footprint of events.

How will virtual existence contribute to, or challenge, sustainable progress?

Positive sustainability impacts	Negative sustainability impacts
<p>Reduced movement and travel emissions: Travel by audience members, crew and performers is consistently reported as one of the main contributors to the carbon emissions of events. Audience travel alone is estimated to make up 80% of a music festival's carbon footprint, at 127,000 tonnes CO₂e (Powerful Thinking 2015). For virtual events, audience travel will be reduced. But travel will still be a major source of carbon emissions for hybrid events.</p>	<p>Energy usage: Metaverse-powered virtual events are enabled by data centres that run AI and cloud services. These data centres require large amounts of energy and water. This highlights the urgency of decarbonising the entire electricity supply. The added capacity needed to support large-scale virtual events and a broader transition to hybrid and virtual existence will require significant investment in grid decarbonisation.</p>
<p>Reduced movement and transport emissions of products: The production of a concert or festival requires the transport of equipment such as sound and lighting systems and temporary infrastructure. Transitioning from physical to virtual events will reduce associated transport emissions. In the art space, virtual museum or gallery tours reduce the need for the movement of art through touring exhibitions and loans. The decarbonisation of art and exhibition transport poses a key challenge for museums and galleries (see www.org.uk/art-for-your-world).</p>	<p>Hardware requirements: To truly immerse in a virtual experience, high quality hardware such as VR headsets are required. This comes with all the associated negative impacts associated with hardware production (see section 2.3).</p>
<p>Reduced waste from events: Virtual events produce less physical waste. At live events waste is generated through the sale of food, beverages, and merchandise, as well as set design, decoration, exhibition displays, and marketing or branding overlay. Production materials, food, beverage, and serveware represent 45% of an event's carbon footprint (excluding audience travel). Each event attendee generates 2.14 kg of waste on average (Isla 2023).</p>	<p>Impact on cultural education and socialisation: There are concerns about the ability for virtual worlds to replicate the experiences in the physical world. The benefits of social interaction, sensory experiences, and collective enjoyment are mostly removed when attending virtual events.</p>
<p>Access to entertainment: Virtual events and existence will enable a large number of people to access different or new culture and arts experiences that were previously inaccessible due to physical or financial barriers (though barriers of digital and technological access will remain).</p>	<p>(Unequal) Access to entertainment: Access to technology and internet connectivity is not equitably distributed, meaning certain groups and populations will be excluded from virtual events.</p>
<p>Social learning theory: People are impacted by the information they encounter and the behaviours they see modelled in virtual spaces, and this can be used to encourage sustainable attitudes and practices. Individuals are influenced by other social media users' green behaviour, forming a drive for environmental responsibility and leading to sustainable purchase attitudes (Zafar 2021).</p>	<p>Consumerism: The increasing amount of time people spend in virtual retail spaces is driving consumerism; shoppertainment is the next wave of commerce. "In a poll conducted by shift, a London-based fashion site, 74% of people aged 14-27 confirmed that they had felt pressured to purchase new clothes after watching haul videos and 66% admitted to purchasing more clothing after joining TikTok" (Comar 2023). On the supply side, high street fast fashion is now being "threatened" by ultra-fast fashion companies such as Shein and Temu, which bring out new products each day to keep pace with TikTok's trend cycle. A fast fashion garment is worn just seven times on average before disposal, and people's appetite for consuming new garments continues to speed up (Harris 2024; Deighton 2023).</p>
<p>Mitigation of biodiversity loss and other environmental impacts: Large events such as music festivals can have significant impact on local biodiversity if not properly managed by measures such as controlled access areas and eco-friendly infrastructure (GAI 2024). Transitioning to virtual events eliminates these negative impacts.</p>	

Table 13. Positive and negative sustainability impacts for virtual existence, with a particular focus on audience experience.

Making physical events greener

Physical experiences such as concerts, festivals, or theatre performances have a significant carbon and environmental impact. An early estimate from Bottrill (2008) suggested that live music performances in the UK generate around 402,000 tonnes of GHG emissions annually. This estimate would likely be different now, as UK grid emissions have reduced and updated data on production transport has become available, but the figure includes music venues, performer and fan-related travel, generator usage, trucking, and tour buses. Energy usage is required to support the lighting and AV of performances and the operation of venue and event infrastructure. Embodied carbon is associated with materials and products – from the timber, metals, and plastics that go into infrastructure, sets, and branding, to food service packaging and cups, and the food and beverages themselves. Additionally, audiences add to the resource consumption – through fast-fashion outfits purchased for the occasion, or camping equipment and other consumables needed to spend a weekend at a festival. The UK music camping festival industry generates an estimated 25,800 tonnes of waste annually (visionsustainableevents.org). Moving people, artworks, equipment and infrastructure around results in significant carbon emissions from travel, transport, and freight.

There has been movement towards the greening of festivals and music events in general. The European Green Festival Roadmap 2030 (yourpe.org/know-how/green-roadmap), for example, plans to mitigate negative sustainability impacts through transitioning to renewable energy generation, zero waste to landfill initiatives, eliminating single-use plastics, encouraging low carbon transport, and local sourcing of food and beverages. Singer Billie Eilish is among a range of artists who have partnered with Reverb (reverb.org) to reduce the environmental footprint of their tours. Actions include engaging with fans to raise awareness on environmental issues, eliminating single-use plastic from touring venues, providing exclusively plant-based food for artists and crews, and implementing waste management strategies backstage. Meanwhile, the band The 1975 invested in carbon removals to offset their tour's negative impact after calculating expected carbon emissions from band travel, staging and catering at concerts (McLaren 2023).

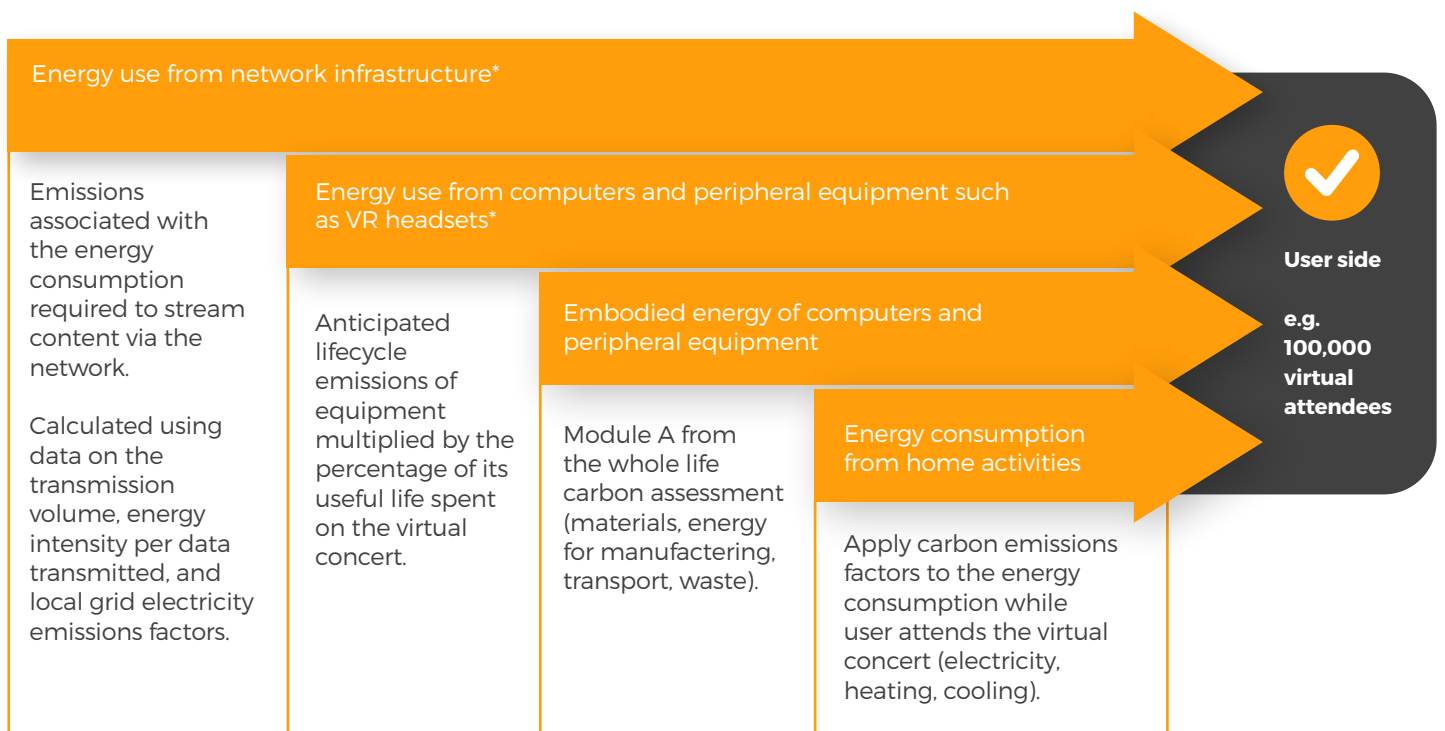
The majority of emissions related to music events stem from operational transport, supply chain and audience travel (Preussen 2022). Practical solutions to reduce audience travel have not developed beyond the promotion of low-carbon transportation options. Transitioning to a more virtual mode of consumption may present practical solutions to reduce these emissions.

How do we sustainably develop this area?

Some virtual experiences have been shown to have a lower carbon footprint than their physical counterparts. A study by the University of Michigan, for example, estimates that a virtual conference generates 66 times fewer GHG emissions than a physical equivalent (Faber 2021).

A fuller understanding of carbon emissions from virtual events and existence should be based on a robust methodology of carbon accounting. A carbon accounting framework will allow the Creative Industries to identify potential key sources of emissions and implement targeted interventions to mitigate negative impacts. Moreover, carbon accounting can guide the design and accelerated adoption of more sustainable technologies, ensuring that as the Creative Industries evolve they will do so sustainably.

There is currently no unified approach to measuring the impact of virtual events, although there are examples to learn from such as The Networked Condition’s work to calculate carbon associated with digital art and creative media (andfestival.org.uk/networked-condition). This report therefore proposes that the Creative Industries operationalise a model that evaluates all of the potential carbon impact areas. A high-level GHG framework is proposed as a starting point, which can then be modified and applied to calculate emissions from virtual events. A product-based WLCA should evaluate all stages of production and consumption. Figure 7 presents an example of emissions analysis for audience streaming of a virtual event.



*The European average for an hour of streaming video was calculated to be 56 CO₂e/hour (Carbon Trust 2021). This incorporates emissions associated with the average grid intensity in Europe (based on 2020 figures), an assumed representative mix of user devices (such as computers or televisions), and the average bitrate associated with streaming.

Figure 7. Proposed product emissions analysis WLCA for audience streaming of a virtual event.

On the consumption side, with potentially hundreds of thousands of virtual attendees at a digital-first event, the key emissions sources to consider include the energy use of network infrastructure, computers and peripheral equipment, the embodied energy of hardware, and the energy consumption from home activities. The Carbon Trust (2021) reports that the impact of video streaming can be disaggregated into the emissions originating from viewing devices, TV peripherals, home routers, network transmissions, and data centres (Figure 8).

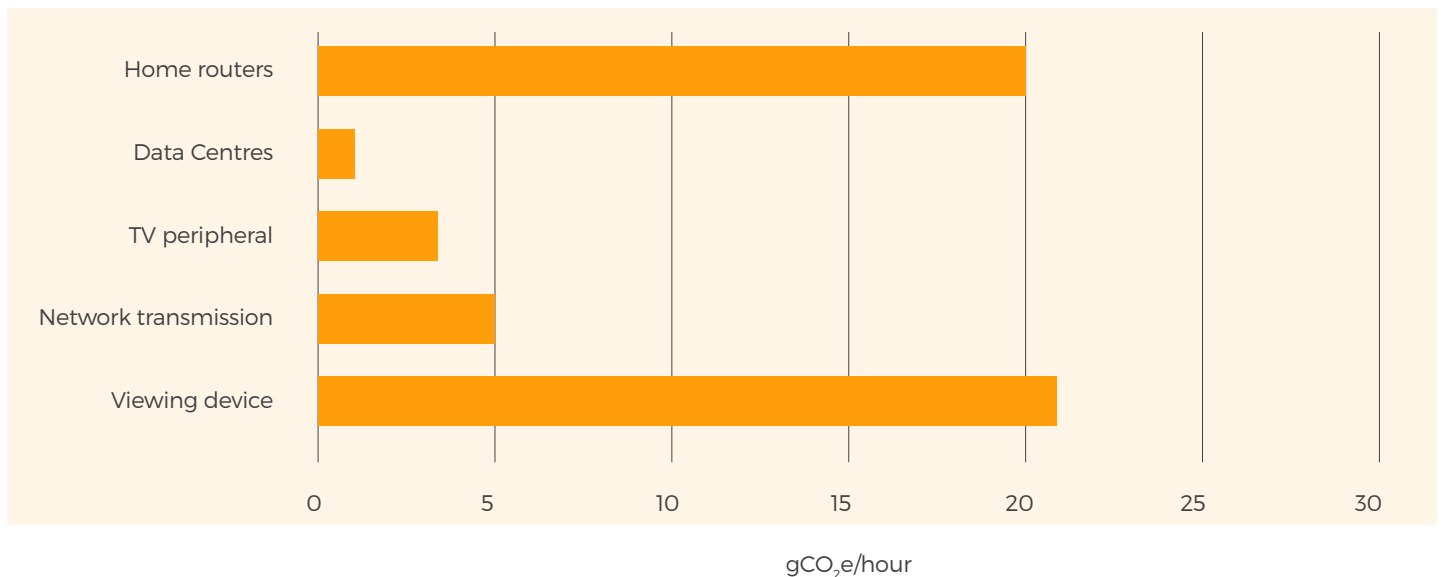
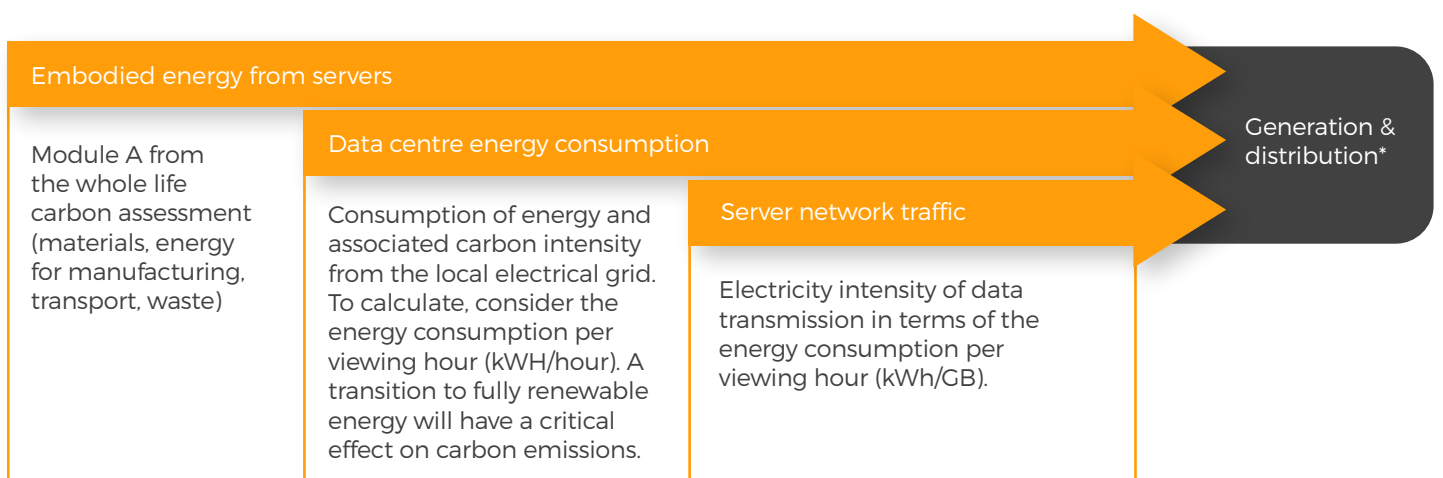


Figure 8. Estimated emissions from one hour of long video streaming, based on European average in 2020 (Carbon Trust 2021).

Carbon emissions will also be released during the generation and distribution of a virtual event (Figure 9). In this scenario, a digital-first event will generate emissions at the data centre and throughout the transmission of the content. Data centres will represent a large component of the carbon footprint of a virtual event. Data centre energy consumption is estimated by multiplying the energy intensity of data centres by the duration of streaming. A 2020 estimate of energy intensity per viewing hour by a selection of DIMPACT members sets this at 1.3 Wh/hour (Carbon Trust 2021).



*In this framework, we are assuming a production model of digital first. For completeness, livestreamed performances will require the consideration of the following additional emissions sources: emissions associated with the travel of streaming equipment, and emissions associated with the organisation and production of the physical event.

Figure 9. Proposed generation and distribution emissions analysis WLCA.

There are important limitations with this framework in forward-casting emissions associated with events. Lack of publicly available data on end-user device mix and/or aggregate representation of energy data makes it difficult to validate the existing carbon emission estimates of granular activities in livestreaming and consuming virtual events. Furthermore, the non-linear relationship between data and energy usage complicates the accuracy of event footprints, as more data processing does not automatically require more energy use until network capacity must be upgraded or expanded (Carbon Trust 2021).

Potential areas for avoided emissions

It is important to acknowledge the potential avoided emissions that will stem from the rise of digital-first virtual events. Annually for UK summer music festivals, 78,155 tonnes of CO₂e emissions originate from audience travel, of which less than half are from public transport (Powerful Thinking 2015), and audience travel makes up 43% of emissions from the UK music industry (Bottrill 2008). Virtual events would eliminate this almost entirely. Furthermore, 145,000 tonnes of CO₂e are produced annually from energy consumption at venues and festival generators. To assess avoided/reduced emissions, event organisers in the Creative Industries should consider the following emissions sources:

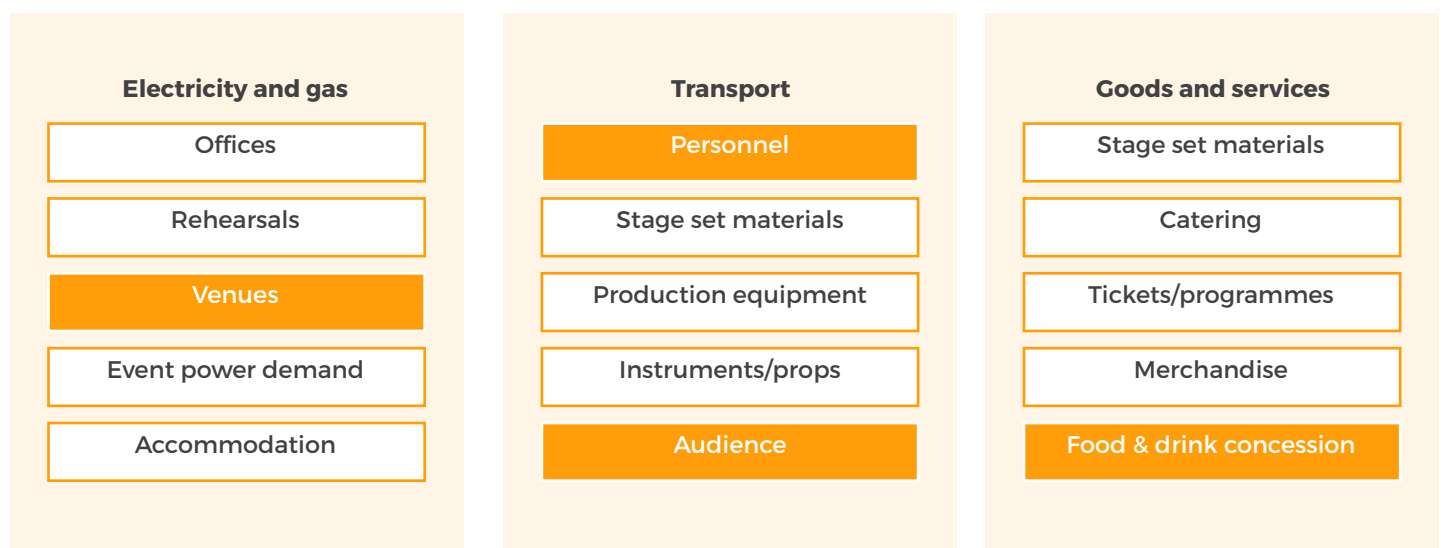


Figure 10. Emissions sources for physical events. Highlighted boxes are sources potentially avoided by switching to digital-first virtual events.

Developing a unified framework for virtual event WLCA will support the Creative Industries in making informed decisions by providing quantifiable data on the environmental trade-offs of different event choices. An accurate understanding of carbon emissions can help determine whether the benefits of virtual events in reducing travel-related emissions outweigh the emissions from increased server usage and electronic waste. By anticipating the carbon impact of technologies such as VR and the metaverse, the Creative Industries can cement their commitment to sustainable and environmentally-positive development.

Key themes

Leadership: Reimagining the way entertainment is produced and consumed is a forward-thinking stance for the Creative Industries. Virtual experiences are in their infancy, and the Creative Industries can lead the way by ensuring that this transition does not increase overall carbon emissions.

Data acquisition and reporting: There are no carbon accounting methodologies for virtual events, and data is limited. Comprehensive data collection on traditional and virtual experiences will enable sustainable decision-making.

Integrated solutions: Data centres are likely to be a large contributor to the emissions from virtual events, and investing in the decarbonisation of data centres at scale is necessary to reduce any negative carbon impacts.

Actions

The following actions will help the Creative Industries to manage the sustainability implications of virtual existence:

Category	Action	Effort	Timeframe
Carbon accounting	Develop capacity around carbon accounting: Create a working group comprising experts in entertainment, technology, and carbon accounting. This coalition will be tasked with formulating a sustainability strategy for virtual events.	High	Short term
	Develop standards: Collaborate with entertainment and carbon accounting working groups to develop a framework for carbon accounting that addresses the emissions from the user side and generation and distribution of virtual events.	High	Short term
	Update data: Standardise data sharing to enable holistic and data-based decision making. Ensure data is up-to-date to avoid faulty assumptions (DIMPACT 2023).	Medium	Medium term
	Data collection: Create data collection templates to simplify carbon accounting of virtual events and ensure these templates can be embedded into virtual event platforms.	High	Medium term
	Accounting methodology: Develop a consistent methodology of carbon accounting for virtual events. This may include: <ol style="list-style-type: none"> 1. Defining a clear scope and setting the boundaries of the virtual event to cover all relevant emissions sources; 2. Collating any relevant emissions factors for network and streaming emissions; 3. Compiling supplementary research estimating the impact of the metaverse and future virtual events; 4. Implementing and operationalising data collection templates. 	High	Long term
	Case studies: Conduct baseline studies to assess carbon emissions of virtual events to provide usable case studies.	Low	Long term

Category	Action	Effort	Timeframe
Energy usage	Data centre energy use: Identify and promote the use of sustainable energy centres for the generation and distribution of virtual events through approved supplier lists.	Medium	Medium term
	Procurement: Set guidance on the procurement of data centre services for virtual events. This guidance should include mandatory proportions of renewable energy sources used by data centres.	Low	Short term
	Energy efficiency: Promote energy-efficient devices and digital infrastructure to produce and consume virtual entertainment, such as TVs, data servers, and other in-home devices (DIMPACT 2023).	Medium	Short term

Table 14. Sustainability actions for virtual existence. See Table 3 for “effort” and “timeframe” definitions.

Research gaps

Research gap	Issue
Comprehensive emissions for metaverse and virtual gaming platforms.	Actions and decisions in virtual spaces, whether events, competitions or transactions, are easily divorced from their environmental impact in the eyes of the user, and the heat, water and carbon impacts of the data centres keeping these technologies running are remote and hidden. There is a requirement for transparency and visibility when it comes to the environmental impact of the metaverse, AR and VR technologies, as virtual existence is becoming more accessible and commonplace.
Carbon footprint of one-off virtual events based in the metaverse.	

Table 15. Research gaps for virtual existence.

A sustainable future for the Creative Industries

This section explores the critical steps required to advance the Creative Industries toward a more resilient, innovative, and sustainable future. At the core of these efforts is the need for directive industry leadership – driving a unified vision, fostering collaboration across stakeholders, and addressing challenges with decisive, strategic action.

In parallel, enhancing data acquisition capabilities is essential to unlocking insight, improving sustainable decision-making, and driving decarbonisation across the sector.

Finally, adopting integrated, future-proof solutions will enable the Creative Industries to adapt to emerging technologies while constantly driving down emissions in an increasingly dynamic and complex environment. Together, these priorities will equip the Creative Industries to lead with purpose, embrace innovation, and set a benchmark for sustainable development.

1. Directive industry leadership

There is a pressing need for top-down direction when it comes to decarbonisation in the UK Creative Industries. As in most sectors, there needs to be a transformative approach to leadership, with a focus on driving innovation, collaboration and systematic change to enable the Creative Industries to cut emissions and ensure their future.

There are specific areas that leadership should focus on, including:

Technical leadership

- Educate and raise awareness of the sustainability implications of integrating new and emerging technologies.
- Shift the sector's mindset to prioritise sustainability alongside creative and technological objectives. Drive awareness that sustainability is critical to ensuring the survival and success of the Creative Industries.
- Embed sustainability into creative processes and all decision-making gateways. Sustainability can no longer be treated as a separate process.
- Set clear sustainability KPIs such as reducing carbon emissions, reducing/appropriate handling of waste and embracing circular principles.

Collaborative leadership

- Leaders should support relationship building across the sector by connecting creatives, sustainability experts, technology developers and government bodies to share best practice, data and responsibility across a value chain.
- Support the Creative Industries supply chain to decarbonise through collaboration and capacity building. Support productions and creatives to examine their supply chain, connecting them to sustainable suppliers as alternatives to suppliers they are familiar with.
- Reach out to adjacent sectors and industries who may be able to provide decarbonisation services and sustainable alternatives.

Innovation leadership

- Adopt emerging technologies that support decarbonisation objectives for the Creative Industries.
- Champion creative carbon reduction solutions by sharing best practice and success stories.

Policy-driven leadership

- Leaders should work with policymakers to establish sector-wide sustainability guidelines, including incentivising more green productions and lower carbon outputs, and working towards carbon neutrality across the Creative Industries.
- Develop and advocate for certification programs that recognise sustainable practices in the sector.

Financial leadership

- Leaders should develop incentives and funding structures that reward sustainable approaches to the adoption of emerging technologies.

2. Data acquisition and reporting

To ensure a sustainable future for the UK Creative Industries, a data-driven approach is critical. Acquiring accurate and comprehensive data on carbon emissions will enable the Creative Industries to truly understand the environmental impact of the use of new and emerging technologies in creative work. Data will also help the Creative Industries to identify and isolate high emissions areas and develop interventions to specifically tackle them. Transparent reporting will foster accountability, ensure regulatory compliance and encourage widespread adoption of sustainable practices.

There are specific areas and actions the Creative Industries should focus on:

Consistent carbon methodology for emissions quantification

- Define objectives for the carbon calculator, for example, to quantify the environmental impact of a full production cycle (for a film, TV show, video game, etc.). The method needs to be flexible enough to include technology processes as and when they integrate into production lifecycles.
- Define goals and boundaries for emissions calculations, ensuring alignment with other standards including the Greenhouse Gas Protocol and Science Based Targets initiative.
- Work to define consistent parameters (e.g. scope 1, 2, and 3 emissions), data boundaries, and measurement units to enable comparability and interoperability.
- Initiate pilot projects to test the methodology, gather feedback and refine the process based on real-world application. Work to iteratively improve the method as data collection improves.

Sector-wide reporting frameworks

- Develop corresponding reporting frameworks for productions to self-report their emissions and environmental impact.
- Sector leaders maintain flexibility, allowing the methodology to evolve as new technologies, regulations, and data sources emerge.

Empowering creatives to gather and report data

- Publicise the development and release of the reporting framework so organisations and individuals can access it and begin to integrate it with their business processes.
- Invest in educating stakeholders on how to implement the methodology. Provide guidelines, toolkits and case studies to ensure widespread adoption.
- Publish sector-wide reports to showcase progress, highlight best practices and encourage other stakeholders toward sustainable goals.

Commit to and invest in strategic R&D

Early findings from this report were shared by the CoSTAR Foresight Lab with experts across the CoSTAR Network. This review identified the following strategic research and development priorities:

- For data and measurement:
 - Explore the feasibility of measurement of energy use for creative technology across the production workflow.
 - Explore methods to measure the impact of supply chain emissions associated with virtual production and other new and emerging technologies.
 - Explore methods for productions to analyse and identify lower emission services from data centre providers.
- For optimisation:
 - Explore the feasibility of software-controlled energy usage minimisation in studios and across workflows.
 - Explore the feasibility of approaches to minimise AI energy usage (e.g. small language models).
 - Conduct detailed action research linked to specific projects or organisations, to create new models and frameworks.
 - Explore how the Creative Industries can support and scale low emission data processing and storage innovations.
- For devices and physical assets:
 - Explore new approaches to the procurement, management and disposal of devices and hardware associated with convergent technology across production workflows.
 - Understand the carbon capital cost of building and equipping new virtual production facilities.

3. Integrated future-proof solutions

Reducing the environmental impact of emerging technologies in the Creative Industries requires integrated solutions that address energy consumption, resource management, and waste across the entire production lifecycle. Key strategies include adopting energy-efficient technologies (like cloud computing powered by renewables), transitioning to circular economy models (for devices and physical assets), and promoting sector-wide collaboration and standardisation. A combination of technological innovation, policy frameworks, and sustainability-driven decision-making will be essential for guiding the Creative Industries toward a greener future.

Actions could include:

Energy-efficient data centres and cloud solutions

- Sector leaders can identify data centre providers that use renewable energy sources to run their facilities. This can be consolidated into a preferred provider list and publicised for stakeholders to use.
- Select providers with certifications like LEED (Leadership in Energy and Environmental Design), Energy Star, or Uptime Institute's sustainability certifications.
- Encourage productions to partner with data centre providers to co-develop innovative technologies like liquid cooling or advanced waste heat recovery systems.
- Encourage productions to implement strategies like data deduplication, archiving cold data, and optimising workloads to minimise resource usage.

Supporting a circular economy for infrastructure and devices

- Advocate across the sector for responsible disposal and recycling of server components, batteries, and other IT equipment.
- Promote the use of product-as-a-service (PaaS), where productions and individuals lease devices and return them for refurbishment and upgrades rather than disposing and repurchasing.
- Utilise device sharing platforms between productions, similar to the Library of Things, where individuals borrow equipment that they do not need to use all of the time.

Appendices

Appendix A: Report methodology

Literature review and data collection

The objective of the initial literature review was to identify technologies impacting music, theatre, film, gaming, and events. The review was not limited to carbon or sustainability impacts to ensure a broad understanding of trends in the Creative Industries. More than 150 sources were reviewed, covering academic papers, blog posts, podcasts, and industry position papers. This was supplemented by integrated qualitative insights from a curated list of interviewees, bringing in real-world expertise and sector-specific insights.

Horizon scan

This process focused on recent and upcoming trends with the intention to sketch out a vision of the Creative Industries' future, but also to apprehend shifts with the potential to completely change sector norms. These trends were curated according to newness and impact on the Creative Industries, with case studies identified for each. These examples were then grouped by theme to help identify more specifically how they would transform the sector going forward.

Thematic consolidation of emerging technologies

Individual insights from the literature review, interviews, and horizon scan were consolidated into wider themes via internal workshops and sector feedback. This ensured a diversity of topics to form the basis of the carbon analysis. The final thematic areas are detailed in Appendix B.

Sustainability analysis

Based on the thematic areas identified, a sustainability analysis was undertaken to understand how the selected technologies might impact the carbon and environmental footprint of the Creative Industries, which resulted in the four future sustainability impact areas discussed in the main body of this report. Figure A1 provides a visual overview of the various topics covered by the sustainability analysis. For each of the future sustainability impact areas, the sustainability analysis derived a description, a summary of potential positive and negative impacts, and overall implications and recommendations for the Creative Industries.

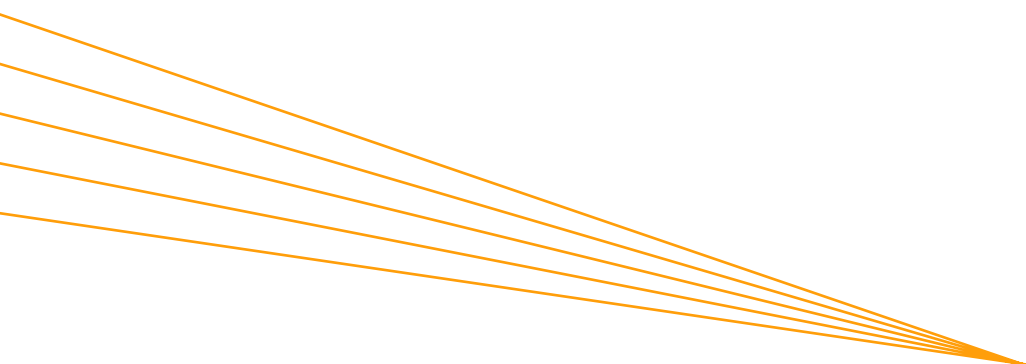




Figure A1. Visual overview of the key topic areas covered by the report's sustainability analysis.

Appendix B: Emerging themes

This section outlines the emerging technology themes that were identified through literature review, expert interviews, and a horizon scan.

Democratisation

The process of making advanced technologies accessible and usable by a broader range of people, organisations, and industries. Traditionally, technologies have been accessible only to a select few due to factors like high costs, specialised expertise, or complex infrastructure requirements. Democratisation seeks to break down these barriers and make technologies more widely available and usable.

Trend	Description
Use of generative AI in music production	<p>Generative AI can generate melodies, harmonies and rhythms to inspire or aid musicians in their work. Artists and producers can leverage AI tools to explore diverse musical styles and experiment with unique sounds, expanding the boundaries of musical genres. Individuals who have a passion for music but lack technical skills or the ability to play an instrument can use these tools as a route into music production.</p> <p>Implications:</p> <ul style="list-style-type: none"> • Deep learning technology should not replace humans' unique artistic creativity, but lower barriers to entry. • It is important to value the role of the human mind in the process of creating art, the emotions involved and the creative depth associated with creating music in such a way (Weng 2020). <p>Evidence:</p> <ul style="list-style-type: none"> • OpenAI's Jukebox models music and the human voice directly as raw audio. Jukebox can generate melody, compositions, timbre, and rudimentary singing in a variety of genres and styles.
Co-writing screenplays and theatre scripts with language models	<p>Large language models (LLMs) are becoming useful in co-creative applications. These models show promise for automatic story generation as an augmentative tool for human scriptwriters and screenwriters. Hierarchical generation of stories can produce an entire script from a single user-provided summary of a central dramatic conflict. For example, Dramatron, based on an LLM, uses an input log line to generate an entire script with a title, list of characters, a plot, location descriptions, and dialogue (Mirowski 2023). The user can intervene at any stage of the generation, soliciting alternative generations, or editing output text. In this way, the human interactively co-writes the script.</p> <p>Implications:</p> <ul style="list-style-type: none"> • To provide inspiration for writers. • Generation of alternative choices and world building (script writing): more than just providing a creative spark for the main story, the model can populate the universe of the story. • Using the system for learning and analysis: by prompting the system, writers could indirectly search the language model for literary styles and elements. • Potential of AI as tool for TV screenwriting (script writing): some participants suggested this tool could be employed in a TV writers' room, to help with writing formulaic scripts. <p>Evidence:</p> <ul style="list-style-type: none"> • Short films <i>Sunspring</i> (2016), <i>It's No Game</i> (2017) and <i>Solicitors</i> (2020) had scripts that were generated using LLMs
Potential to become a creator in the metaverse: every user can create immersive content	<p>Metaverse technology is fast evolving, with the use of VR headsets, haptic gloves, augmented reality (AR) and extended reality (XR) enabling users to experience high levels of interaction and immersion. User-generated content (UGC) is a term describing digital content produced, altered, or contributed by users within virtual environments, or content (such as images, video, text, and audio) created by users instead of professionally employed content creators. It includes various media, such as 3D models, virtual clothing, artwork, structures, scripts, etc. UGC has huge potential, with the market expected to be worth \$25 billion by 2025 (AEY Metaverse Guild 2023).</p> <p>Implications:</p> <ul style="list-style-type: none"> • The metaverse's democratisation is driven by UGC, which enables users to customise digital spaces to suit their needs and preferences. UGC gives users the tools to personalise their online personas, encouraging self-expression in the digital sphere. • On traditional web platforms, content creators often relinquish ownership rights and control over creations once they upload them. However, with blockchain technology, UGC creators can establish verifiable ownership and retain full control over content. Blockchain's immutable and decentralised nature ensures that content remains tamper-proof and resistant to censorship. • Content creators can now transform their digital creations into unique, non-fungible tokens (NFTs), which represent ownership of a particular piece of content or digital asset. These NFTs can be bought, sold, and traded on blockchain marketplaces, allowing creators to monetise their work directly. <p>Evidence:</p> <ul style="list-style-type: none"> • Platforms such as <i>Roblox</i> (79.5 million average daily active users in the second quarter of 2024; Roblox 2024), <i>The Sandbox</i>, and <i>Fortnite</i> (1.1 million average daily users in October 2023; Howarth 2025) are metaverse spaces where users can create avatars and interact with other gamers within their own virtual universe. Platforms such as Artsteps.com and Artplacer.com offer users the option to create their own VR or online art galleries.

Virtual production

Virtual production (VP) employs LED panels as backdrops for a physical set, on which video or computer-generated imagery (CGI) is displayed in real-time. The “virtual world” surrounding the set is visible to the camera, actors, and crew and can be made to closely approximate the appearance of a real set or outdoor location. With virtual production, CGI work that would otherwise be completed in post-production needs to be ready during pre-production. It has the potential to produce highly detailed and realistic visuals faster with greater efficiency and lower production costs.

Trend	Description
<p>Building virtual stages to amplify cinematic experience and reduce costs (pre-production)</p>	<p>The VP market was estimated to be worth around \$3 billion in 2023, and is projected to grow to \$10 billion by 2032, with a compound annual growth rate (CAGR) of 14.7% (Fortune Business Insights 2024). Augmented reality (AR) allows screen content creators to overlay digital elements onto the real world – for example, using scanned 3D models of prop-house offerings so designers can audition objects on location before pulling them from storage, increasing efficiency. Sets loaded with furniture, props, wall colour, and wardrobe on virtual stand-ins can be shared as digital files by leveraging AR. This will be helpful to set designers as they will be able to experiment virtually via their devices, make changes, choices, and suggestions before deciding on physical changes.</p> <p>Implications:</p> <ul style="list-style-type: none"> · Instead of transporting people to locations or bringing them together on sets, studios are turning to VP solutions to replicate those production elements in a cost-effective way. · VP allows for the digital creation of realistic environments – including digital recreations of real-world environments such as heritage sites or other sensitive locations – reducing the need for location shoots and, in turn, reducing a production’s carbon footprint and other environmental impacts. · Actors report a better experience performing against LED screens than green screen backgrounds. <p>Evidence:</p> <ul style="list-style-type: none"> · Flexibility of features, such as volume and background change, speeds up production processes. VP has been used in various films and television shows, including <i>The Mandalorian</i> and <i>The Lion King</i> (Winter 2021).
<p>Accelerated visual effects (VFX) growth (during production)</p>	<p>Visual effects (VFX) work involves the creation of realistic and imaginative visual elements for movies, TV shows, and digital media. Although most VFX work is completed during post-production, it must be carefully planned and choreographed in pre-production and production.</p> <p>Implications:</p> <ul style="list-style-type: none"> · In 1990, eight of the 10 highest-grossing films at the box office used conventional VFX. By 2019, only one movie among the top 10 did so, with the rest using digital animation or higher-level visual effects (Dinç 2023). · The introduction of streaming platforms such as Disney+, Apple TV+, HBO Max, Peacock, and Paramount+ between 2019 and 2021, in addition to Netflix and Amazon Prime, has increased demand for VFX. This has led to the establishment of production centres worldwide, with India emerging as a prominent hub for VFX. The global VFX market size reached \$10 billion in 2023, and IMARC Group expects the market to reach \$18 billion by 2032, with a CAGR of 6.7% during the period 2024–2032 (imarcgroup.com/visual-effects-market). <p>Evidence:</p> <ul style="list-style-type: none"> · CGI has been used to craft lifelike creatures, landscapes, and action sequences, from the realistic dinosaurs in <i>Jurassic Park</i> to the alien world of Pandora in <i>Avatar</i>. Additionally, motion capture technology records the movements of actors and translates them into digital animations. Andy Serkis portrayed Gollum in <i>The Lord of the Rings</i> trilogy (2001–2003) and Caesar in the <i>Planet of the Apes</i> series (2011–2017) with the aid of sophisticated VFX (Sokolova 2023).

Virtual existence

As of April 2024, there were 5.4 billion internet users worldwide, which equates to 67.1% of the global population, according to [Statista.com](https://www.statista.com). The next evolution of the internet will likely include a highly immersive metaverse powered by AI, with near-instantaneous interactions made possible through advances in connectivity. By 2026, it is projected that 25% of people will spend at least one hour a day in the metaverse for work, shopping, education, social and/or entertainment, according to Gartner (2022). The first indicator of this is “generational gravity”: younger generations are spending more time in virtual, immersive worlds and using AI tools. The second is “technological gravity”: a large volume of capital “is flowing into metaverse and AI technologies” and “interconnected ‘phygital’ worlds – a blend of physical and digital – will become the norm that [people] gravitate toward in both work and life, not just in the realm of games” (Kulasooriya 2023).

Trend	Description
<p>People are increasingly identifying with their digital avatars</p>	<p>Digital avatars will continue to shape virtual existences. The global digital avatar market is predicted to hit \$156 billion by 2032, shifting from niche metaverse communities to widespread acceptance (Ryder 2024). These avatars represent a person’s digital identity and respond to user commands and facilitate social interactions. Digital avatars can be fully customised – from physical features to clothing and personality traits – though sometimes this requires the purchase of digital assets, occasionally in the form of NFTs. As technology advances and becomes more democratised, avatars will transfer through different gaming worlds, increasing personal attachment to this digital identity.</p> <p>Implications:</p> <ul style="list-style-type: none"> • Metaverse-based communities will grow stronger as emotional ties to avatars increase and metaverse-based entertainment events flourish, likely increasing the time people spent in virtual digital spaces. • Brands traditionally associated with “physical world” items such as clothing have already collaborated with gaming companies to provide accessories for avatars. Fashion brands can further leverage digital avatars as potent channels for self-expression. • Concerns are manifesting in mainstream discussion around people identifying too much with digital avatars and becoming isolated or using anonymity to enact malicious behaviour in the metaverse. <p>Evidence:</p> <ul style="list-style-type: none"> • Digital avatar and fashion platforms like Colonii, Genies (which secured \$150 million in funding in 2022), and Brand New Vision are investing in high-fidelity, state-of-the-art personas (Ryder 2024). Since “The Doggies” (a collection of 10,000 Snoop Dogg-themed avatars, distinguished by over 150 different traits) was launched on <i>The Sandbox</i> in February 2022, “avatars worth 7,654 ETH (Ethereum, a cryptocurrency) have been traded on the OpenSea platform. Based on the underlying creator fees of 5%, the account TheSandboxCollections was able to generate about 382 ETH in fees, which corresponds to about \$670,000 at the March 2023 ETH price”, clearly signalling a market for native digital avatars (Blockchain Research Lab 2023).

Trend	Description
<p>Increasing level of asset ownership in the metaverse</p>	<p>The concept of ownership may evolve such that virtual assets become as valuable and significant as their real-world counterparts. Virtual assets can include digital artworks, vehicles, designer clothing, and real estate in the metaverse. Ownership of these virtual assets signals status and prestige.</p> <p>Implications:</p> <ul style="list-style-type: none"> · The realm of what franchises can offer as products is expanding – for example, film producers are able to make NFTs of stills, scenes, bloopers and other elements. <p>Evidence:</p> <ul style="list-style-type: none"> · <i>Sports Land</i> is a digital experience within <i>The Sandbox</i> metaverse, selling digital fashion to football fans. Within a month in late 2022, in the run up to the FIFA World Cup, over 1,721 NFTs were sold for over \$15,000 – excluding the 5% marketplace fee – to 1,265 unique addresses or users (Blockchain Research Lab 2023).
<p>Virtual worlds become so immersive and realistic that they create an alternative avenue for marketing, events, and other experiences</p>	<p>With technologies such as VR headsets and metaverse maps, the virtual world is becoming increasingly immersive and realistic for players. As people spend more time in these virtual realities, companies are identifying opportunities for marketing, events, and other experiences. Through immersive storytelling, interactive virtual experiences, and digital showcases, brands are harnessing the power of the metaverse to forge deeper connections with consumers.</p> <p>Implications:</p> <ul style="list-style-type: none"> · Growing virtual audiences provides a basis for more metaverse-based entertainment events. · Brands will continue to collaborate with metaverse and gaming companies to provide virtual versions of their products. · Hybrid spaces may lead to increasingly hybridised forms of media, such as interactive fictional TV programmes, or artist performances and film screenings within video games. · Marketing will have an increasing presence in virtual spaces due to the large amount of time people spend there. This may result in a backlash or a negative impact on user experience, particularly as advertising and in-game purchases are embedded to create different tiers of metaverse experience. <p>Evidence:</p> <ul style="list-style-type: none"> · In January 2023, Calvin Harris performed as an avatar during a virtual concert that merged music, technology and artistry for those with PICO VR headsets in Asia and Europe. The show had real time interactivity between the artist and fans during its live broadcast, and fans could dance with one another and add live visual elements to the show such as constellations and fireworks in the sky (wavexr.com). Olafur Eliasson's visual-first artwork <i>Earth Speakr</i> (earthspeakr.art) is made to be experienced via VR headsets in galleries. <i>Smoking Gun</i> by Fastfamiliar (fastfamiliar.com) is an example of app-based game theatre, usually experienced via smartphone, but also possible to experience in situ with a group of strangers. Events enabling virtual engagement for in-person groups have also risen in popularity – for example, Somerset House's <i>Now Play This</i> (nowplaythis.net).

Unconscious algorithmic shaping

The adaptability of AI is evident in how people consume content. With digital content now ubiquitous, AI technologies play a role in shaping user interactions with information, entertainment, and advertisements across various platforms. By using advanced algorithms and data analysis, generative AI can create content that specifically appeals to certain audience groups and matches their content preferences. Also, as AI becomes more sophisticated in generating realistic and engaging content, distinguishing between human and AI-created works is increasingly challenging. This blurring of lines raises questions about authenticity and trust, critical factors in consumer behaviour.

Trend	Description
<p>Technologies such as AI and VR are unconsciously determining the reality and authenticity of entertainment through pre- and post-production editing</p>	<p>The combination of AI and VR tools presents a realm of new production editing opportunities that unconsciously determine the reality of what we consume. Instead of requiring multiple retakes to correct mistakes, AI and neural rendering can be overlaid onto shots to correct facial movements or alter scripts. This technology is improving in its ability to alter scenes in a photorealistic way, ultimately enabling higher-quality editing and corrections than previously possible. Post-production corrections present concerns around the ethics of using an actor's likeness in ways they have not consented to, as well as the unconscious shaping of viewers' perceptions of entertainment. Deepfakes of actors, artists, and other influential people are becoming more photorealistic and have amassed fans. The companies responsible for generating these deepfakes have also raised significant capital investment.</p> <p>Implications:</p> <ul style="list-style-type: none"> · Policy will be required around the use of increasingly sophisticated editing and deepfake technologies as their outputs become more convincing and risk manipulating audiences. · Practices around hiring actors may change, with individuals selling their likeness for continued AI-enabled use rather than working on multiple projects with multiple companies. · AI-generated film and TV may become a norm, impacting how media is created and received. · Increasingly tailored editing provides opportunities to increase media accessibility, particularly for those with sensory impairments. <p>Evidence:</p> <ul style="list-style-type: none"> · Filmmakers are using deepfake technology in mainstream content. Martin Scorsese's <i>The Irishman</i> used deepfake technology to de-age actors and in <i>Star Wars: Rogue One</i>, AI was used to produce the deceased actor Peter Cushing's character, Grand Moff Tarkin (Klingler 2024).
<p>Unconscious personalisation in content consumption</p>	<p>Platforms driven by UGC, such as TikTok, represent a shift away from traditional media channels, such that content can be produced and consumed by everyone. Compounding UGC with algorithms that drive viewers to different ends of a spectrum creates a polarising divide. Emerging functions of AI include the creation of tailored film shorts and trailers to pique viewer interest. These clips are determined by an algorithm that considers a viewer's past viewing history, their background, demographics, and general likes. Individuals are presented different material based on what they have liked in the past.</p> <p>Implications:</p> <ul style="list-style-type: none"> · Media and entertainment consumption will become increasingly polarised, causing potential divides between different demographics and affecting the ways in which people see the world. · Audiences may start seeking out slower media that is more author-led than consumer-led, as an alternative to the fast-paced, often aesthetic-driven tailored content of online platforms. · Heavily tailored content is currently the norm on online platforms but may influence the film and television sectors as the influence of this trend grows, with content being commissioned in response to household profiles. · Personalisation capabilities will improve media accessibility, particularly for those with sensory impairments. <p>Evidence:</p> <ul style="list-style-type: none"> · Based on user preferences and past history, Netflix's algorithm personalises not just what it recommends but also how it recommends – i.e. what artwork or imagery accompanies recommended titles. It seeks to provide visual "evidence" for why a title might be good for the user (Chandrashekar 2017).

Skills in emerging technologies

As technologies such as artificial intelligence, virtual reality, and blockchain continue to integrate into the UK Creative Industries, new digital skills will be required across the sector. Traditional artistic and design abilities will increasingly need to be paired with digital literacy, data analysis, and proficiency in tools such as virtual production, generative AI and XR. There will be new and changing roles for creative professionals in a sector where automation and innovation are reshaping the creative process, as well as a need for continuous learning and improvement as these technologies evolve.

Trend	Description
Tech job creation in Creative Industries	Specific new roles are being created within the Creative Industries to enable the integration of new technology into existing environments.
Skills pathways created	Training and education for these new career pathways. In addition, skilled professionals are moving from other industries into Creative Industries to plug skills gaps.
Ethics training for AI implementation	Growing awareness of the ethical implications of AI technology and its implementation. Specific training to ensure ethics are considered when integrating this and other technologies.

Immersion and wearables

Wearable technologies range from head-mounted displays such as VR headsets through to devices which can be implanted under the skin. These technologies can enable multi-modal forms of interactions with or via a digital avatar or artefact, or tangible interfaces. Visual, audio and haptic-related sensory information (e.g. vibration, texture, pain, and force) can be delivered via wearable technologies. Currently, wearables are inching toward maturity but are increasing in capability and use.

Trend	Description
Cognitive interfacing	<p>Cognitive interfacing, or brain-computer interfacing (BCI), refers to the use of measured brain activity to impact digital applications – for example, to control an avatar or play a video game (Nosta 2024). This is achieved via devices such as electroencephalograms (EEGs), which detect electrical activity in the brain and translate it into signals that are understood by a machine. The process is hands-free and is currently used predominantly for medical purposes around rehabilitation and accessibility, but it may suggest a future where games are controlled using one’s mind rather than a handheld controller.</p> <p>Implications:</p> <ul style="list-style-type: none"> • This could change the way people play games or interact in metaverse spaces, removing an equipment barrier and making the experience feel more embodied. • The rehabilitative application of cognitive interfacing demonstrates the therapeutic impacts of gaming, which has more traditionally been seen only as a form of entertainment. Narratives like this help shift the way gaming is seen in the eyes of the public. <p>Evidence:</p> <ul style="list-style-type: none"> • Twitch streamer Perrikaryal is known within the online gaming sphere for using an EEG device to play video games, by linking specific brain activity to specific actions within games (Bardhan 2023). • A report published by the Institute of Electrical and Electronics Engineers finds that BCI gaming with VR improves cognitive functioning in healthy participants, with positive impacts on memory, concentration, visual and spatial tasks (Hadjiaros 2023).

Trend	Description
Museums and galleries digitising art	<p>Several leading museums and galleries are digitising their collections, creating a virtual record of culturally significant objects. This will increase access to a huge array of collections and may emphasise the educational role of these institutions, with people from around the world able to view and learn from artefacts previously inaccessible to them. There will also be economic impacts, with contributions to fields of research, medicine and conservation potentially bringing large amounts of money into the global economy.</p> <p>Implications:</p> <ul style="list-style-type: none"> • Cultural and historical information will be made increasingly available, educating and enriching people around the world – particularly those who previously would have had no means of access. • More material and information made widely accessible may lead to a spike in research breakthroughs. • Digitised collections can displace the carbon impact of viewers travelling to physical sites. <p>Evidence:</p> <ul style="list-style-type: none"> • Research indicates that if London’s Natural History Museum were to digitise its entire collection, it would contribute approximately £2 billion to the global economy. Since 2015, the museum’s digitisation of 4.9 million objects has supported 1,407 scientific papers, and continuing the process could unlock “ground-breaking” areas of research (Davis 2021). The British Museum is also starting the process of digitising its entire collection (Ho 2023). The National Gallery and New York’s Metropolitan Museum of Art both provide virtual tours, and the National Theatre has captured live performances for VR and streaming. Cirque du Soleil has filmed performances specifically for the purpose of creating VR experiences.
Portable and wearable devices	<p>As of 2020, survey research found that, on a daily basis, 12% of British people watch television on their smartphones and 30% use their phones for gaming (YouGov 2020). Meanwhile, the wearable technology market is predicted to reach \$265 billion by 2026 (MarketsandMarkets 2022). These data points suggest an emerging role for entertainment as a round-the-clock accompaniment, rather than being consumed at specific times of day. This will impact on the kind of content people want from the Creative Industries. As wearables become more commonplace, VR could also become more accessible and popular in the mainstream, providing new opportunities for entertainment.</p> <p>Implications:</p> <ul style="list-style-type: none"> • Addiction to personal devices is a growing issue that will continue to affect populations, especially younger demographics who have grown up using them. This will affect mental health and put pressure on media and device companies to abide by ethical guidelines. • Physical entertainment venues may continue to suffer unless interest in these spaces as a stimulating alternative to “screen time” is renewed. • Media content will continue to be shaped by viewing habits. For example, films may become more “bite-sized” to suit commutes and smaller screens. <p>Evidence:</p> <ul style="list-style-type: none"> • In 2022, virtual reality company AmazeVR launched its first VR concert tour, <i>Enter Thee Hottieverse</i>, across the US with most shows selling out. The company eventually released the concert to at-home viewers through the Meta Quest App Lab store to enable a wider audience to access the experience (priced at \$9.99), clearly signalling a market (Copans 2022).

Decentralisation and transparency

Blockchain technology has immense potential to reshape the way content is created, distributed and consumed, and directly tackles longstanding sector challenges such as copyright infringement and piracy. On a blockchain-based platform, artists can upload original works, self-publish, control licensing options, and manage distributions. Royalty payments can be programmed into a smart contract for every piece of content and can be automatically paid out to the creator upon use. The decentralised nature of blockchain-based marketplaces ensures transparency and allows users to interact without costly intermediaries and enable direct connections between artists and fans. A critical component of the blockchain revolution is the NFT, which provides artists with provable ownership of their unique digital creations, from music tracks to digital artworks. For consumers, it provides unique, personalised ownership of digital media content.

Trend	Description
Blockchain for accountability	<p>The use of blockchain and AI in supply chains helps track consumption and consolidate data to identify areas for improvement, whether in resource consumption or more general areas of efficiency. Blockchain has a key role in supply chain operations and resource flows by providing transparency and accountability as well (Hong 2024). As the tracking of operations is publicly visible and accessible when stored in the blockchain, companies are under increased scrutiny and are pressured to be more responsible with their logistics processes and their environmental impact.</p> <p>Similarly, digital and materials passports categorise equipment based on how resource- and energy-intensive they are, leading to more widespread public literacy around the waste and overconsumption associated with certain products and industries (Wilde 2024). There will be greater demand on companies to adopt technologies around transparent sustainable practice and for them to assure consumers that processes and supply chains are responsibly managed.</p> <p>Implications:</p> <ul style="list-style-type: none"> • Public awareness around environmental standards will increase as compliance information becomes more accessible. This will pressure companies to adhere to such standards to secure the faith of consumers. • Environmental policy and legal requirements will evolve with technological possibilities such as materials passports, raising the bar for what is acceptable. Processes in production and distribution that are currently commonplace may be outlawed. <p>Evidence:</p> <ul style="list-style-type: none"> • Tech-enabled transparency specialist Provenance uses blockchain technology to store sequential information on the sourcing, production and sale of company products, creating an open record of product origins and impacts, and encouraging brand transparency (provenance.org). In the blockchain, the data remains in an immutable, openly accessible form, creating a useful track record for the client. • Provenance’s software also enables businesses to gather information regarding these stored claims and use smart tags and website embeds to link this data to physical products. This adaptation of blockchain technology means that companies can make a structured group of claims concerning the sustainability and impact of their business or products – something that Provenance calls the “transparency framework” – which can serve as a selling point. • Platform Flux Resources utilise supercomputing and distributed carrier sensor/document flows to predict global shipping disruptions for clients with 30% more accuracy (Hong 2024). Similarly, Canada’s Maersk-owned Sixfold project leverages AI to fuse various data sources and identify emerging risks (sixfold.ai). These applications demonstrate how the combination of blockchain and AI technologies can merge data sources to analyse risks and optimise supply chains. • Changes in EU regulations mean that, from 2027, industrial and EV batteries will be required to have a “digital battery passport”, which includes information on the battery model as well as information specific to the individual battery and its use, with sectors such as textiles and electronics expected to follow in 2030 (Rizos 2024).

Trend	Description
NFTs as entertainment/exclusive collectibles	<p>NFTs have emerged as a new dimension of entertainment, sold as exclusive collectibles in tandem with live events, or as event tickets themselves (Moongate 2024). NFT tickets work as an extension of live events by offering extra benefits as well as more secure identity verification for purchasers due to their blockchain-based storage.</p> <p>Implications:</p> <ul style="list-style-type: none">• NFTs are increasingly offered as an extension of entertainment, from live events to cinematic franchises, providing new forms of buy-in and participation.• There is currently no overview of the carbon impact of this new format of entertainment engagement or consumption. <p>Evidence:</p> <ul style="list-style-type: none">• Web3 marketplace Yellowheart has created a “ticketing metaverse” where people can buy NFT tickets as well as merch, music and exclusives in the form of NFTs (Thomas 2023). Creating this space around ticketing also intends to avoid unfair price rises, ticket scalpers and zero resale profit.• The “Twilight Pass” for Robbie Williams’ 25th anniversary metaverse-based tour included metaverse-based “land gifts” and apparel-based Robbie Williams-branded NFTs. The pass itself also served as a digital collectible (Bybit 2024).

Appendix C: Technology carbon analysis

This section examines the carbon impact of technologies seen as most transformative for the future of the Creative Industries.

VR, AR and the metaverse		
What are they?	VR places the user in an immersive, digitally simulated world, experienced via a headset. AR overlays digital and sometimes interactive elements onto a view of the real world, for instance via a smartphone screen. The metaverse refers to any virtual online platform in which people can interact. Such interactions can range from co-operative gaming to attending events in VR to taking a tour of a virtual museum within a metaverse platform.	
How are they used in the Creative Industries?	VR and AR are used in gaming. <i>QuiVr</i> , for instance, is a VR game where players engage in archery in an entirely virtual world, whereas <i>Pokémon Go</i> uses AR by augmenting the players' view of their real-life surroundings (via their smartphone) with digital Pokémon for them to interact with. Both technologies are also used in events; entire concerts and parties can be held and accessed via VR technology, while other events encourage attendees to use AR on their smartphones to access digital overlays of extra material and information (see, for example, Hitti 2018). In film and television, virtual production uses VR to facilitate casting and location scouting – meaning they can be done remotely to save carbon and costs, but also to enable access to remote, dangerous or rare sites (Bodini 2024).	
Carbon impacts of hardware manufacturing	Virtual reality headset	The estimated lifelong carbon impact of a virtual reality headset is between 70 and 200 kg CO ₂ e (APL 2024).
		Using recycled gold, silver and copper in a VR headset reduces its lifetime environmental damage by 36% (Andrae 2017).
	Specific product cradle-to-grave footprints	The total product footprint for Apple's Vision Pro is 335 kg CO ₂ e (Apple 2024).
		Total GHG emissions for VIVE XR Elite (including headset, battery cradle, controllers and packaging): 92.64 kg CO ₂ e (HTC n.d.)
		Total GHG emissions for VIVE FLOW: 34.83 kg CO ₂ e (HTC n.d.)
Carbon impacts of usage	Annual CO ₂ emissions for a "light gamer" using a mid-range PC (US average) is 351 lbs (Greening the Beast n.d.).	
	Annual CO ₂ emissions for an "extreme gamer" using a mid-range PC (US average) is 1,105 lbs (Greening the Beast n.d.).	
	Annual CO ₂ emissions for an "extreme gamer" using a high-end PC (US average) is 1,356 lbs (Greening the Beast n.d.).	
	US gaming platforms represent 34 terawatt-hours a year in energy usage – more than the entire state of West Virginia – with associated carbon dioxide emissions equivalent to over 5 million cars (D'Anastasio 2020).	

Gaming consoles (non-VR/AR)

What are they?	Gaming consoles are devices designed solely or primarily for playing video games. Popular games consoles include the Sony PlayStation, Microsoft Xbox Series X/S and Nintendo Switch.	
How are they used in the Creative Industries?	Personal gaming is a mainstream form of entertainment. E-sports tournaments have grown in size in recent years, with professional teams engaging in competitions held in huge arenas full of spectators as well as in online spaces. The gamification of products and events further speaks to the popularity of gaming – videogames can be used as promotional material for franchises or function as spin-offs.	
Carbon impacts of hardware manufacturing	Gaming consoles	Sony creates 1.6 kg CO ₂ e for every PS4 manufactured.
		Since the PlayStation 4's release in 2013, approximately 8.9 billion kilograms of carbon dioxide have been generated.

Blockchain, cryptocurrencies and NFTs

What are they?	The blockchain is an open-source network whereby a list of digital transactions is stored securely along with surrounding data, providing a traceable record of activity. Cryptocurrencies are digital currencies such as Ethereum or Bitcoin that are used to make digital transactions; they use cryptography to prevent counterfeiting. NFTs refer to digital identifiers certifying an individual's ownership of a one-off (i.e. non-fungible) digital entity. For example, a digital artwork can be "minted" as an NFT to certify its ownership by its purchaser, no matter how many copies are made of it. Its storage on the blockchain proves this authenticity.	
How are they used in the Creative Industries?	Blockchain technology is useful for company accountability – for example, around carbon efficiency – as storing information on an open-source technology incentivises good practice (Hong 2024). NFT event tickets are also a recent development: stored on the blockchain, they assure customers that their purchase is secure and incorporate identity verification to reduce the risk of scams or unfair resale (Thomas 2023). NFTs are also used as part of the entertainment package itself, being sold as exclusive merchandise and collectibles.	
Carbon impacts of manufacturing	One NFT artist's half a year NFT carbon cost is equivalent to driving a car an estimated 838,000 km or boiling a kettle 3.5 million times (Akten 2020).	
Carbon impacts of usage	Bitcoin, the most polluting cryptocurrency, uses 1,183.58 kWh per transaction, which equates to 1,775 lbs of CO ₂ (Bignell 2023).	
	The cryptocurrency Polygon uses 90.18 kWh per transaction, which equates to 135.27 lbs of CO ₂ (Bignell 2023).	
	Global Bitcoin mining is reported to use energy at a rate of 127 terawatt-hours annually, according to the Cambridge Bitcoin Electricity Consumption Index. This exceeds Norway's entire annual electricity consumption, with a single blockchain transaction estimated to consume 60% more energy than 100,000 credit card transactions (Kearney 2024).	
	Lancaster University estimates a 30% increase in carbon emissions by 2030 due to the use of cloud computing (Espinosa n.d.).	
	The data centres and data transmission networks that underpin digitalisation accounted for around 330 megatonnes CO ₂ e in 2020 (including embodied emissions), equivalent to 0.9% of energy-related GHG emissions (or 0.6% of total GHG emissions; Rozite 2023).	

AI	
What is it?	Artificial intelligence (AI) is the computational ability to perform tasks that typically require human intelligence and thinking abilities (Copeland 2025). This can include the perceived ability to make decisions, to recognise and respond to speech, or to appear to “learn” from and analyse data.
How is it used in the Creative Industries?	AI can be used to produce art forms such as music, film and digital images, as well as branding and marketing materials. AI can be used to write entire scripts and event plans and is also used in post-production for film and television to add VFX and tweak footage (Weisenberger 2022). There is debate around originality and plagiarism when it comes to AI-generated works, as AI models are trained on data from the internet – including original pre-existing creative works. However, the technology can also be seen as an enabler, breaking down barriers to creativity for those new to their practice (Marr 2023). Moving away from production to consumption, AI is used to recommend content and products to consumers based on their previous viewing and shopping habits.
Carbon impacts of hardware manufacturing	Generating the electricity used in training the language model BLOOM emitted an estimated 24.7 tonnes of CO ₂ e. Estimated emissions increase to 50.5 tonnes if accounting for all processes ranging from equipment manufacturing to energy-based operational consumption (Luccioni and Viguier 2023).
Carbon impacts of usage	<p>The equivalent of one ChatGPT query was estimated to cost 4.32 g of CO₂. For comparison, a Google search is 0.2 g per query (Plan Be Eco 2024).</p> <p>ChatGPT emits an estimated 7.6 tonnes of carbon dioxide per year, over twice the amount that is emitted by an individual person, which is 3.6 tonnes per year (McLean 2023).</p> <p>In creating a single image, DALL-E 2 emits approximately 2,500 times less CO₂e than a US-based artist, and approximately 310 times less than an India-based artist (Tomlinson 2024).</p> <p>In creating a single image, Midjourney emits approximately 2,900 times less CO₂e than a US-based artist, and 370 times less than one based in India (Tomlinson 2024).</p> <p>Stable Diffusion XL, the most carbon-intensive image generation model, generates 1,594 grams of CO₂e for 1,000 inferences, which is roughly equivalent to 4.1 miles driven by an average gasoline-powered passenger vehicle (Luccioni and Jernite 2023).</p>

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CoSTAR Foresight Lab
Goldsmiths, University of London
New Cross
London SE14 6NW

costarforesightlab@gold.ac.uk
costarnetwork.co.uk/labs/foresightlab



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