Virtual Production's Role in Carbon Reduction and Net Zero Production in the Screen Industries

Future Observatory Cultural Policy Fellowship Report

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FUTURE OBSERVATORY

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the DESIGN MUSEUM

STUDIO ULSTER

Ulster University

UKRI Arts and Humanities Research Council

FIG 1 STUDIO ULSTER CURRENTLY UNDER CONSTRUCTION AT BELFAST HARBOUR STUDIOS, BELFAST, N. IRELAND JUNE

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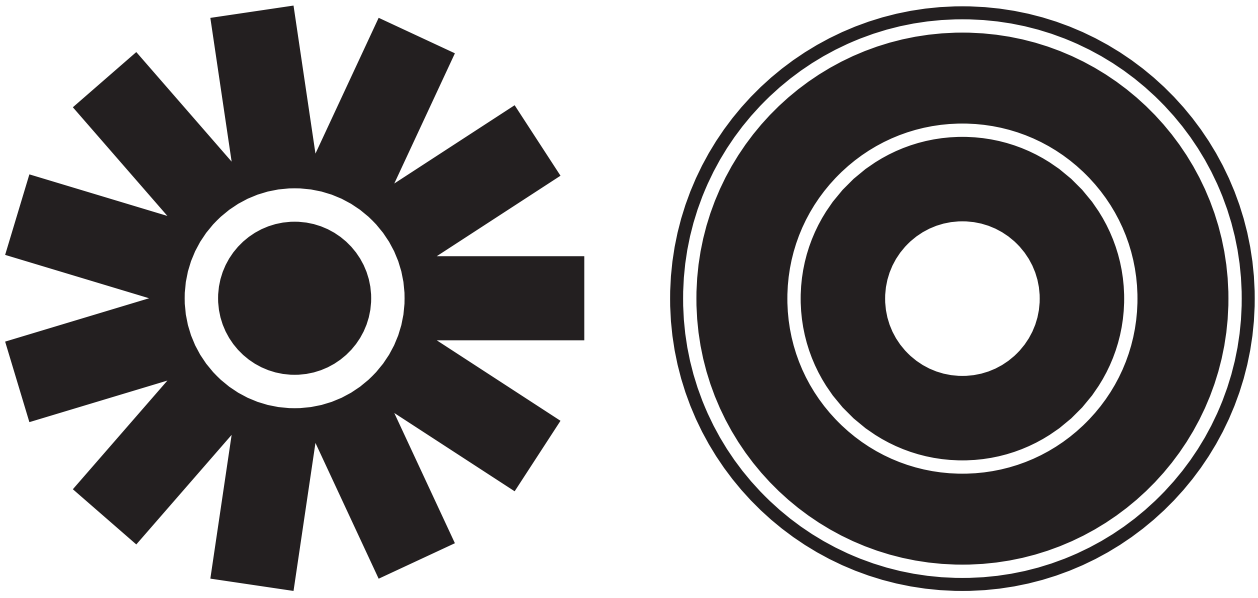
Abstract



This policy report investigates the role of Virtual Production (VP) in reducing carbon emissions within the screen industries. It highlights the transformative nature of this nascent technology and its potential to revolutionise production workflows whilst at the same time significantly reducing carbon emissions in the production cycle of film, television, animation, games and other new emerging digital entertainment forms. It is a technology solution that will also support ambitions across the screen sector to push towards net zero content production.

KEY THEMES

The study explored five interrelated themes as follows:

1 What is VP and its associated use cases?
2 VP's potential to support carbon reduction
3 The technology barriers
4 Key areas of concern and drivers and incentives for change
5 What is stopping us?

KEY AIMS:

→ To explore Virtual Production's role in reducing carbon use and reaching net zero in the screen industries
→ To determine if VP use could enhance our market competitiveness nationally and internationally
→ (Making assumptions based on the green potential of VP) Understanding what needs to happen to support the wider adoption of VP and what the barriers are.

The report highlights the significant environmental benefits of virtual production and outlines how it can reduce carbon emissions by 20% to 50% compared to traditional film production methods. Higher depending on deployment. However, there are some gaps in our understanding to unlock the full benefits of this new technology stack. Increasingly productions are using carbon calculators to gain a greater understanding of carbon use in content production. BAFTA's Albert or the Producers Guild of America's 'Green Production Guide' offer solutions for this. These calculators are a good starting point that now need to factor in the nuances of VP's technology

stack. Virtual production has at a high level, three additional layers of complication that need consideration:

1. **POWER CONSUMPTION:** not unique of course but power needs particular to LED Volumes or LED video walls and data processing that consume significant power need new data base information for accuracy with no two solutions or pipelines currently the same in the field.
2. **HARDWARE MANUFACTURING AND DISPOSAL:** The environmental impact of creating and ultimately disposing of large amounts of LED panels and some other associated high-tech equipment is not yet well understood.
3. **SOFTWARE AND CLOUD SERVICES:** The carbon footprint associated with extensive cloud computing, rendering and data storage is not well understood in the creative industries.

Ideally, we need to create a carbon calculator designed specifically for the purposes of VP such as ALBERT or Julie's Bicycle as experts in the space this could be achieved by:

1. **USING EXISTING FILM PRODUCTION CARBON CALCULATORS:** Starting with established models then factoring in the nuances of VP.
2. **SUPPLEMENT WITH IT CARBON CALCULATORS:** Given the 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 the technology.
3. **ENGAGE EXPERTS & CONTINUOUS LEARNING:** As an emerging field, VP needs to collaborate with sustainability experts and build awareness amongst industry professionals to fully unlock the green potential on offer.
4. **ADVOCATE & COLLABORATE:** Advocate for policy that will support dedicated carbon calculators and collaboration amongst studios, technology providers and sustainability experts to create more precise tools.

Another core area of carbon saving achieved using VP is on travel emissions. Travel and on-site fuel use currently account for half of the industry's carbon footprint. This report underscores the significance of virtual production and highlights its importance in mitigating environmental impact. Virtual production encompasses a range of cutting-edge technologies such as Virtual Reality, Extended Reality, Motion Capture, Real-time VFX, 3D world building, and 3D scanning. (Please see the glossary for definitions.) Advancements in rendering technologies, driven by graphics card innovations, power the creation of realistic virtual environments. This

enables the industry to reimagine on-set possibilities or virtual worlds that can mimic the real world and then commit the scene to camera in 'real-time' in the real world. It could be summed up in the context of convergence and mixed realities as a place where the physical world meets the digital.

This report analyses the complex relationship between the screen industries and carbon reduction efforts, emphasising the potential of virtual production to play a significant part in the journey to net zero. Employing virtual production pipelines, or parts thereof, offers many benefits in the context of carbon reduction, with the reduction in travel and location fuel use being among the most notable savings. Many of the largest production houses, including Netflix, now aspire to greatly reduce their carbon footprint globally and have made public declarations about their intentions.

Furthermore, the author acknowledges the significant work already underway by agencies such as Albert and Julie's Bicycle in the UK that are developing carbon calculators and providing guidance for the industry. This report delves into the nuances of nascent production methodologies that are revolutionising how film, television, games, and animation are produced and how they can be made now and in the future. Virtual Production techniques present new opportunities for the UK, and further research is needed to fully exploit these opportunities in both the commercial and environmental senses.

The recent CoSTAR network of labs, announced in June 2023 in the UK and set to be funded by the Arts Humanities and Research Council (UKRI), will form a critical nexus of world-class facilities to support research in this domain. However, the research activity at these four centres can be shaped by policy and funding to maximise benefits to the UK economy. This network will also be the largest of its kind in Europe. Studio Ulster, led by Ulster University in Northern Ireland, will host one of the four CoSTAR (Convergent Screen Technologies And performance in Real-time) Network Labs, set to open in 2024.

This report identifies barriers that hinder widespread adoption and explores both the positive and negative aspects of this paradigm shift. Moreover, it recognises the importance of considering consumer perspectives and their agency in policy discussions about the environmental impact of

these emerging technologies. The report also reflects on the influence and exposure to international manufacturing and technology supply lines that do not originate in the UK.

METHODOLOGY AND APPROACH

Drawing on extensive market research with commercial companies, intelligence gathering, and studio laboratory testing, the author draws from the collective experience of co-founding a large-scale £72m commercial virtual production studio complex in Northern Ireland, known as Studio Ulster and associated R&D&I lab. The report provides insights into the current state of the virtual production industry in the UK. Considering the potential for significant carbon reduction, this report offers recommendations to encourage the accelerated adoption of real-time pipelines in the film, television, animation, immersive, and games sectors of the screen industries. By embracing virtual production, the industry can position itself as a global leader in sustainable screen production and lead innovation in the creation of digital content. However, if VP is not supported in industry, the competitiveness of our studio offerings in a global market will be greatly diminished.

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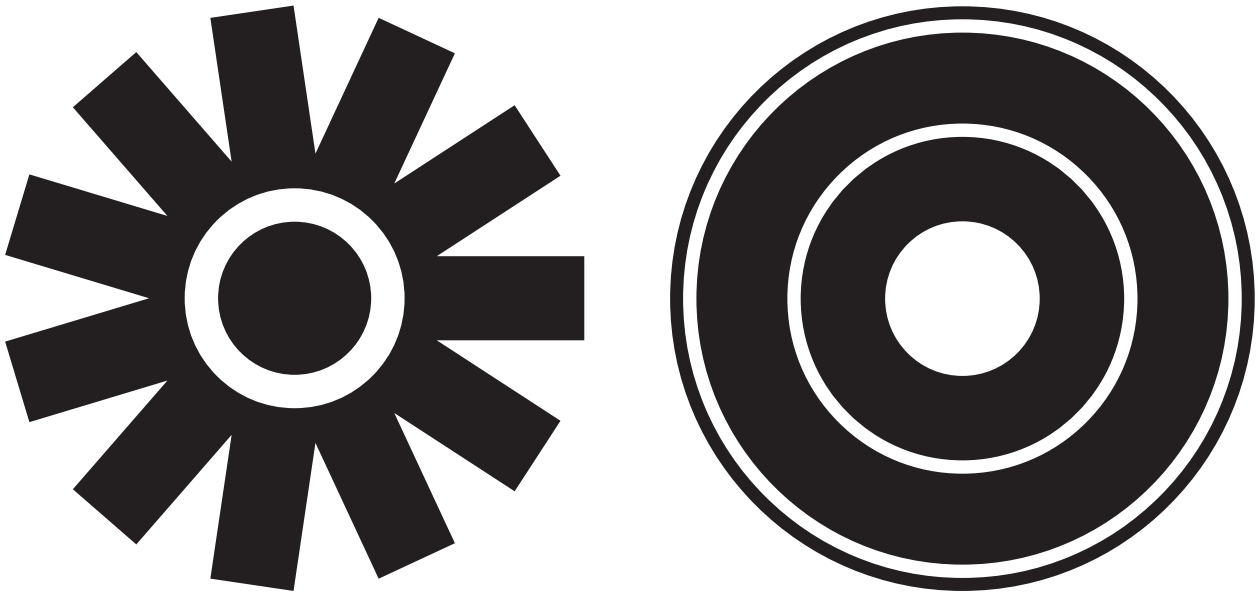
Executive Summary / Key Insights and Recommendations



2.1 THEME 1: WHAT IS THE VP AND WHY IS IT USEFUL HERE?

In light of the government's recent *Creative Industries Vision Strategy* – aiming to grow the UK's creative economy by £50bn and create one million more jobs by 2030 – exploring the potential of Virtual Production (VP) is indeed timely. VP encompasses a wide range of emerging real-time technologies that are revolutionising how Film, Broadcast, Animation, Games, and Immersive content is produced. Recent research has identified the significant potential of this technology stack to reduce carbon use across the content production processes in all these sectors.

2.1.1 By leveraging advancements in computer graphic rendering technologies, these industries are experiencing an unprecedented convergence, melding digital creatives with traditional production methods. These emerging VP workflows, when combined with powerful game engine software, now facilitate the creation of digital representations or malleable virtual twins of our universe. These can be housed within large 'LED Volume' sound stages, virtual reality headsets, and other largely uncommercialised formats. This paves the way for new possibilities, challenges, and opportunities for UK businesses to establish global leadership in this burgeoning field.

2.1.2 In 2021, the North American virtual production market size stood at USD $2.5 billion. In 2022, post-COVID, this grew marginally to USD $2.86 billion. However, the market is anticipated to see a significant surge over the next eight years, reaching USD $7.19 billion by 2030, with a compound annual growth rate (CAGR) of approximately +14% (Global Market Vision, 2021). Market analysts suggest that now is an opportune moment to invest in the skills, training, and infrastructure necessary to capitalise fully on this expected growth in the coming years (Fortune Business Insights, 2021; see Fig. 2 below).

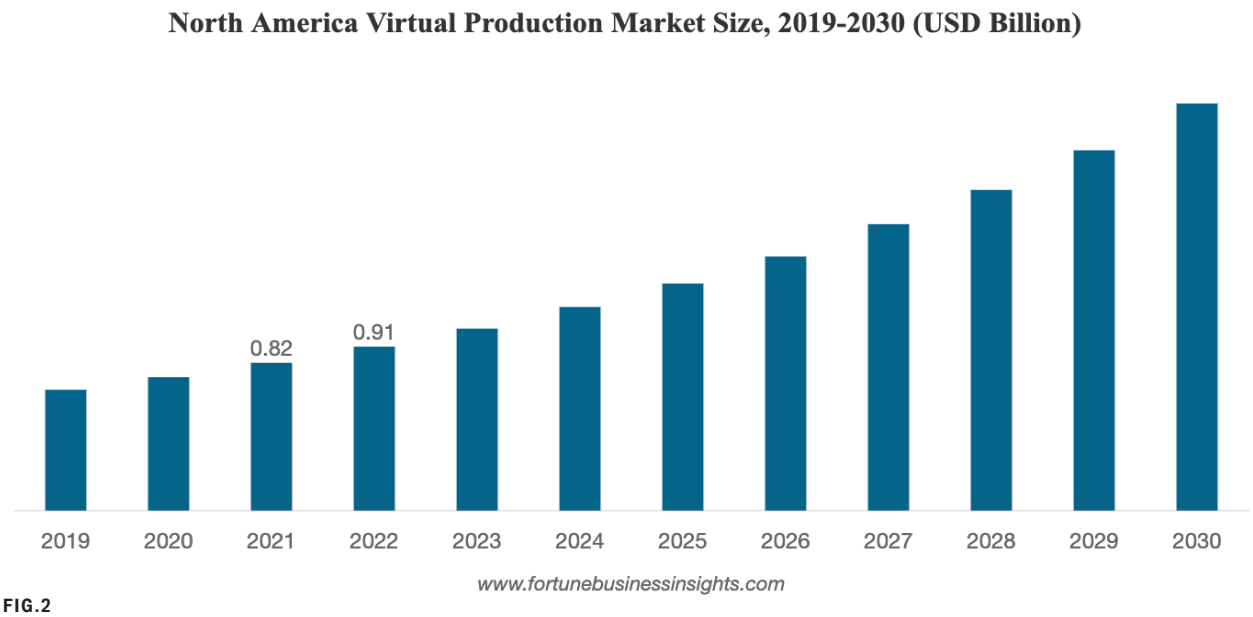


FIG.2

2.1.3 The Broadcast sector is also waking up to the possibilities presented by VP and XR (Extended Reality) technologies for live and pre-recorded formats. The television segment is expected to record the fastest CAGR of 19.7% over the five years globally. The current global VP in broadcast market size was valued at USD $1.82 Billion in 2022 and is expected to expand at the compound growth rate of 18.2% from 2023 to 2030 at a minimum (Grand View Research, 2023).

THEME 2: VP'S POTENTIAL TO SUPPORT CARBON REDUCTION

2.2 In a nascent and emerging industry, there still exists the opportunity to foreground sustainable design methodologies in technology developed and designed from first principles for use in VP. The potential and pressing need for carbon reduction could notably accelerate innovation growth in this sector. A salient feature of VP technology is its ability to significantly curtail the carbon footprint of the rapidly growing screen sector.

2.3 In the specific context of film production, this study's findings, broadly align with previous research such as the Green Screen Interreg Europe report from 2021, indicating that incorporating VP techniques into the VFX pipeline can lead to carbon savings ranging from 20% to 50%. This is particularly evident in hybrid productions where 30% or more of the production is filmed in an LED Volume. Another key insight from this report is the potential for even higher efficiencies, achievable through increased research and development investment, propelling the industry towards the goal of net zero emissions.

2.4 The CoSTAR network will play a pivotal role in advancing this research. Establishing a hive-minded network can significantly speed up sectoral development. As major production companies globally aim for net zero targets within the next decade, the integration of sustainable practices in film and digital content production transitions from being merely desirable to an essential business investment. The capacity to demonstrate a commitment to net zero will increasingly sway investment decisions in favour of the UK. Meanwhile, entities unable to substantiate or certify their carbon credentials in this ecosystem risk lagging in a fiercely competitive global market. It's noteworthy that some current tenders/commissions have already made green credentials a prerequisite for contract award and an obligatory element of delivery.

THEME 3: THE TECHNOLOGY BARRIERS

2.5 The market is currently divided into two primary areas of trade. The first pertains to the service provision and delivery of virtual production pipelines and studio complexes in the UK. The second relates to the systems and technologies required for these services. Predominantly, the technology sector, including equipment suppliers

and manufacturers, originates outside the UK. However, opportunities arise for UK-based companies:

- → To evolve into technology and system developers, thus reducing dependence and market exposure risks associated with external markets like China. This includes offering full traceability and clarity regarding carbon consumption in manufacturing and design processes.
- → To position themselves at the forefront of global technology development and system supply*, especially considering the projected growth. This involves integrating carbon reduction considerations into every design phase, from shipping to eventual disposal.

* We must acknowledge examples of British companies already in the virtual production sector such as Brompton and Mo-SYS.

2.6 Assuming some control over the global demand for new technology solutions can address concerns related to sustainability, market stability, and shipping, particularly their collective carbon footprint. To some extent, the investment by UKRI/AHRC in the recently announced CoSTAR ecosystem will begin to tackle this opportunity with a network of world-class labs and consortia in the UK in this sector. However, parallel to this is the imperative for policies that promote industry adoption. We need measurement tools that either directly reflect or are versatile enough to comprehensively assess the carbon footprint of these novel production methodologies.

2.7 Using the iceberg analogy, what's displayed on screen represents only a minuscule portion of the data processing involved in producing a complex, visual effects-heavy feature film or animation. While carbon calculators exist, those specifically designed to track data processing aren't easily accessible. Virtual Production offers a distinct production environment that upends traditional processes and generates massive data quantities requiring movement, rendering, processing, and eventual archiving. Additionally, the real carbon costs of manufacturing LED video panels for LED volume stages—especially when equipment comes from China or other international locations—present a gap in our information. We lack vital datasets to conduct a comprehensive analysis of the carbon cost and impact of VP in physical production, equipment manufacturing, and data handling.

THEME 4: DRIVERS AND INCENTIVES OF CHANGE

2.8 To maintain its status as a globally competitive and sustainable production ecosystem, *the UK must address new carbon reduction challenges present in the screen industries*. Virtual Production (VP) presents a significant solution. Fresh policy interventions and strategies focused on research, training, and skills development are essential. These will promote the adoption of virtual production

technology across the screen sector, leveraging the green production potential highlighted in this report. The influence of public awareness about green production practices, as a catalyst for change, cannot be underestimated. Large-scale production companies are likely more influenced by market or customer demands than by regional or international policy variations.

2.9 Standardised Green Production Certification models could foster confidence among investors and audiences, speeding up the acceptance of eco-friendly approaches in film production and other VP-enabled content forms. It's crucial to develop these in collaboration with companies active in the UK's film and digital entertainment sectors. For instance, projects that utilize Albert's carbon reduction processes and tools display its logo in their credits. Encouraging companies to adopt greener production techniques is already in motion. The use of virtual production can fast-track these reductions, stimulating job creation, innovation, and new verticals. Producers are actively seeking these measures for incentives and the adoption of sustainable practices.

2.9.1 Austria serves as a European example, introducing a ground-breaking 35% production incentive that, from January 2023, incorporates a 5% 'green bonus' for meeting specific sustainability criteria. This non-repayable subsidy will offer up to €5 million per film and €7.5 million per series.

2.10 *Encouraging the use of renewable energy* in facilities leveraging virtual production and real-time rendering should, in many ways, be the most straightforward shift in the screen industries. Given the considerable energy demands of these new facilities (e.g., Studio Ulster's 1.6GW capacity), it's vital to develop a standard framework for rating carbon efficiencies.

2.11 Championing sustainability in our industry is not only environmentally beneficial but also commercially strategic. *Establishing an industry certification program with global recognition* makes international investment decisions easier. However, the creation of such credentials requires incentivization and funding.

2.12 A key recommendation is to *develop a method for quantifying carbon outputs in virtual production facilities that reflects the complex nature of VP*. This includes understanding data storage, rendering locations, and asset creation.

2.13 Support should expand for existing agencies like ALBERT and Julie's Bicycle, which already play a pivotal role in this sphere. Establishing closer ties between these organizations and the virtual production industry, which can provide real-time data, can help bridge existing knowledge gaps concerning VP's carbon usage. Reliable data sources in this field are limited. For VP facilities to truly comprehend

their carbon footprint, in-depth data analysis could offer many a competitive edge. One proposal is for Studio Ulster in Northern Ireland (a member of the CoSTAR network) to act as a 'living lab', gathering core data from commercial virtual productions. Given its unique position within Belfast Harbour and an on-site university research centre, Studio Ulster is poised to generate significant data beneficial to DCMS/BEIS and other contributors to carbon calculator databases throughout the UK. The CoSTAR Network of labs could be a goldmine in this respect. Some of this work has already begun at Ulster University and is cited in this study. However, more funding is crucial to facilitate this endeavour. World Class Lab status funding could establish a long-term infrastructure in the UK, supplying the necessary data for highly accurate carbon calculators used in VP globally.

THEME 5: WHAT'S STOPPING US?

2.14 *The successful global adoption of VP technology to reduce carbon usage hinges on the workforce's preparedness to seize this opportunity.*

2.15 Predictions indicate that the film and serialised drama production market will experience a slowdown in 2023 and 2024. Early-stage VP vendors and other providers are grappling to develop optimal solutions and ensure the sustainability of their businesses amidst challenges like writer and actor strikes and escalating global costs, increasing staff costs due to limited workforce mobility. Yet, the market is anticipated to surge within the next two years. This growth is attributed to technological advancements such as the introduction of RGBW LED panels (with 'W' representing a fourth white pixel for enhanced colour reproduction), increased automation via artificial intelligence and machine learning, and the broad adoption of these technologies across broadcast, commercial production, games, and animation pipelines. Anecdotal evidence from the industry suggests that a backlog of currently suspended projects will further hasten adoption, a trend observed during the later stages of the global Covid pandemic. A key reason for this is the time-saving advantages VP offers to productions (Deloitte, 2022). However, the industry's potential to harness these benefits will be undermined if it lacks understanding due to insufficient training. It's now crucial to identify and address the significant skills gaps within the industry, as these could lead to potential failures. Efforts are underway to discern the areas of need, but a more substantial investment is required to expedite industry training (Bennet et al, 2023). Addressing these competency gaps is vital, especially for professionals working in both realms of the virtual production market: service provision and technology solutions development. Alongside this, it's essential to disseminate information about the carbon reduction benefits of this technology stack and the evident industry demand for carbon reduction.

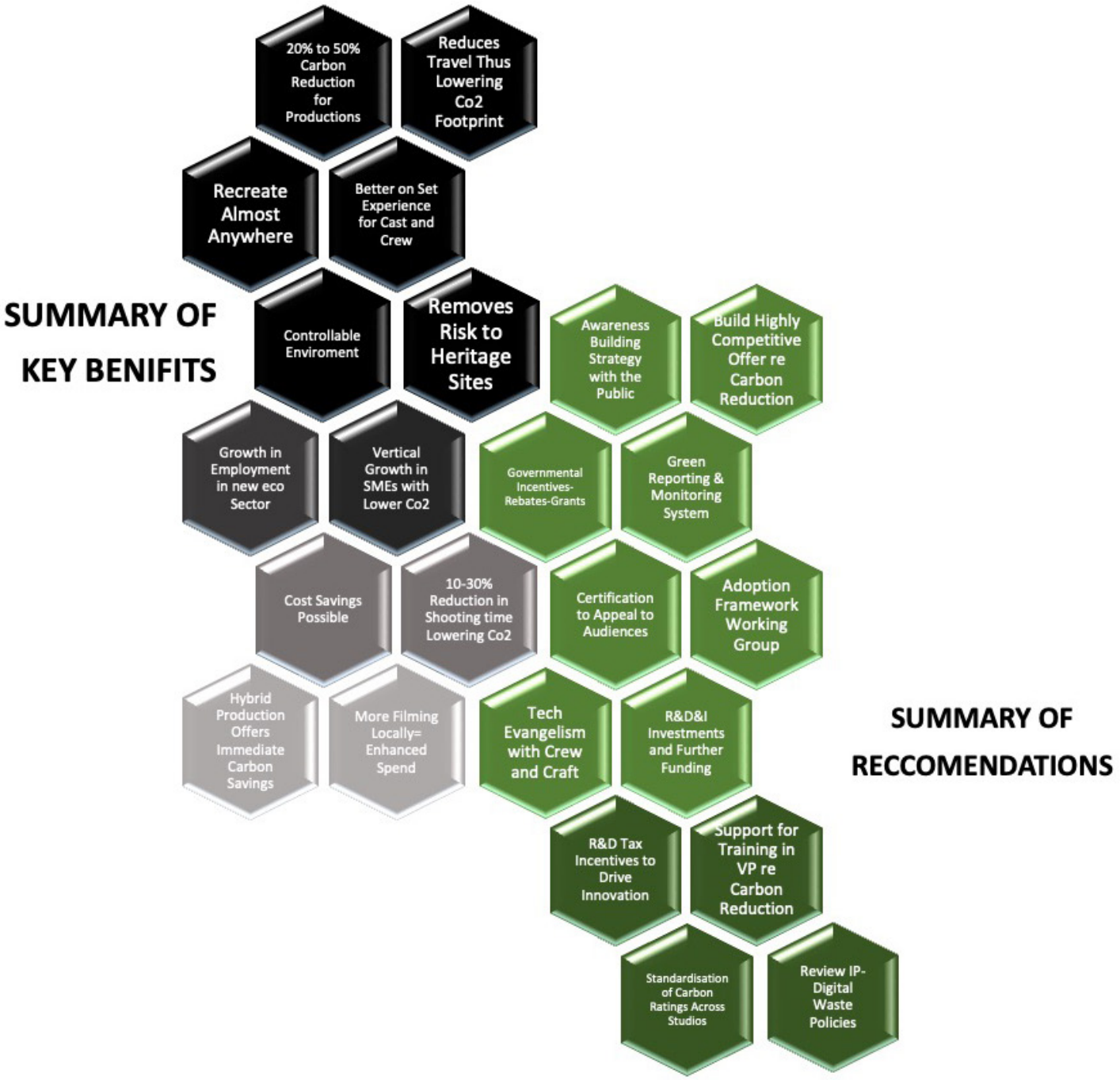

SUMMARY OF KEY BENIFITS
20% to 50% Carbon Reduction for Productions
Reduces Travel Thus Lowering Co2 Footprint
Recreate Almost Anywhere
Better on Set Experience for Cast and Crew
Controllable Enviroment
Removes Risk to Heritage Sites
Awareness Building Strategy with the Public
Build Highly Competitive Offer re Carbon Reduction
Growth in Employment in new eco Sector
Vertical Growth in SMEs with Lower Co2
Governmental Incentives-Rebates-Grants
Green Reporting & Monitoring System
Cost Savings Possible
10-30% Reduction in Shooting time Lowering Co2
Certification to Appeal to Audiences
Adoption Framework Working Group
Hybrid Production Offers Immediate Carbon Savings
More Filming Locally= Enhanced Spend
Tech Evangelism with Crew and Craft
R&D&I Investments and Further Funding
SUMMARY OF RECCOMENDATIONS
R&D Tax Incentives to Drive Innovation
Support for Training in VP re Carbon Reduction
Standardisation of Carbon Ratings Across Studios
Review IP-Digital Waste Policies

FIG.3

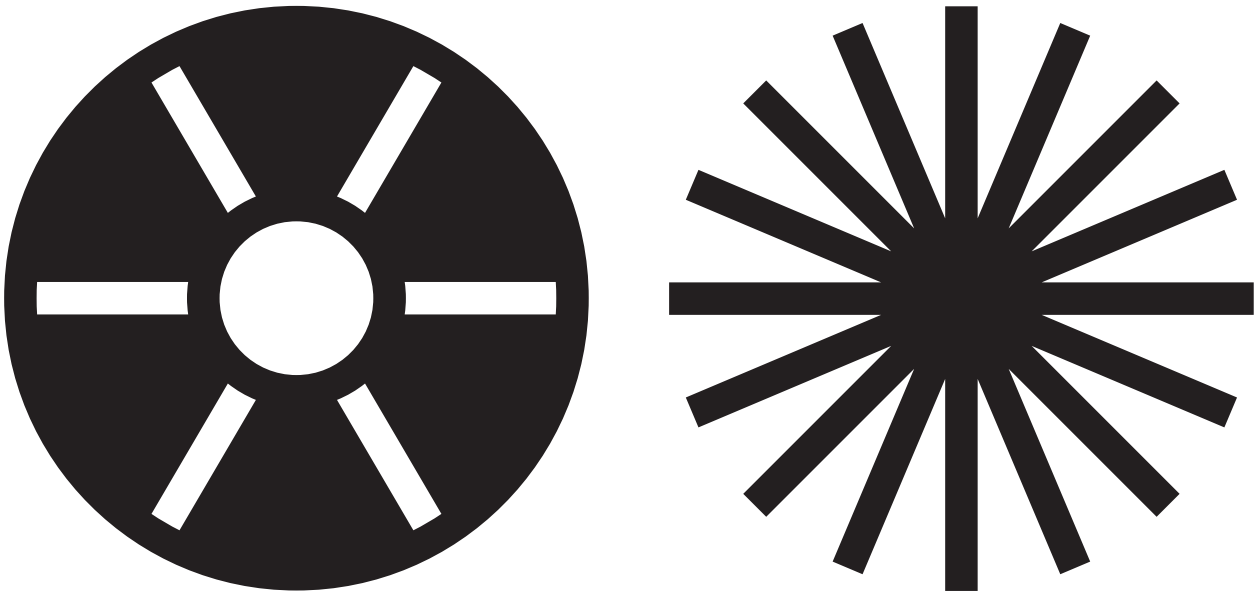
Key Benefits
Significant reduction in the carbon footprint film and broadcast production (20-50% at present)
VP can dramatically reduce the carbon impact in relation to production travel and location fuel used (potentially the largest savings to be made here).
VP with the addition of appropriate physical assets can recreate almost any location in a convincing and highly cost-effective way.
Better on set experiences reported. VP LED offering more creative visual process with the physical presence of an environment on screen replacing greenscreen. Actors reporting better experience in relation to performance v greenscreen. (Willment, 2022)
The environment is controllable offering less risk to investors relative to location-based work globally.
Heritage or other sensitive locations can be recreated in an environmentally sustainable way within a VP stage and do not require large scale on location production teams on site potentially damaging and negatively impacting the site.
VP studios give rise to further employment bringing new technical artists and other new roles in film and television production together.
Vertical growth in SMEs: VP Studios require a wider ecosystem to supply the content and assets needed for production thus driving vertical growth in associated industries (Exiting VFX, animation, games and scanning companies in particular).
Cost savings or added value on Spend: VP can save a production money though most high-end productions are opting to spend the money on more ambitious outcomes using VP for additional locations previously not possible with similar spend profile.
Most time in motion studies done to date show between 10-30% savings on shooting time. This alone has a significant carbon reduction impact through reduced working days.
Immediate opportunity for savings aligning to current production methodologies. The VP process sits comfortably with traditional production techniques and hybrid delivery is likely to be the norm for some time offering immediate route to carbon efficiencies. Vast reductions in materials used for set building.
Regions can augment the types of sets and locations in their repertoire potentially enabling different or larger scale productions to remain and do more filming in these regional locations. i.e., Studio Ulster in Belfast can recreate a Moroccan Desert in golden hour in Belfast Harbour. Rather than the crew leave and fly to Morocco for a short sequence. The location is instead recreated in the harbour.

Summary of Challenges Facing Virtual Production
Still significant gaps in the data sets for carbon analysis. Particularly in relation to manufacturing processes for LED panels. (Largely manufactured in China).
Poor quality stages globally and early-stage technology demonstrations have already damaged first impressions with senior executives impacting adoption.
Regional variations in travel costs, energy, existing crew base and cost of living will determine the success of some new VP studio facilities emerging post pandemic.
Lack of staff and skills shortages will derail the growth of the UK screen industries if not urgently address. Investment is needed to draw more new entrants into 3D VFX and related production pipelines. Training should include green credentials of the medium.
Still distinct lack of knowledge and understanding among existing crew base across the UK in virtual production. These barriers to entry will slow adoption and ultimately the environmental benefits of using these technology workflows.
Initial start-up costs of VP companies are still very high particularly for hardware such as LED.
The technology pipeline is over reliant on China and the development of LED technologies elsewhere internationally. There is a supply chain threat (such as chips from Taiwan) in the event of changing relationships globally and opportunities for incentivising British Companies are needed. Additional benefit would be a reduction in the shipping and transportation of assembled hardware.
The full computing and rendering implication of the technologies is not well understood and requires significantly more research investment.
Many of the leading companies in the sector are North American and capacity for expansion outside the US will be challenged with internal growth in the USA continues. Some US vendors have set up UK Ltd companies already (Halon, Lux Machina as subsidiaries of NEP Group)
The ecosystem that surrounds virtual production including animation, games and immersive are under existential threat from generative artificial Intelligence and machine learning tools. Research is needed to understand the implications of this technology as a force for good in the creative industries. Potential to automate tedious workflows for example.
An accurate and publicly shareable measurement of carbon emissions is essential for the UK virtual production and VFX studios to understand how competitive they are in the context of green credentials globally.
Many large-scale production company executives are risk adverse in relation to adopting new technology stacks. Significant ‘Tech Evangelisation’ work is required to build in new attitudes and investor confidence in the sector.

Recommendations:
To improve the adoption of virtual production workflows and encourage production companies to reduce their carbon footprint and use of greenhouse gases, the following action points can be considered and supported through policy interventions:
Theme 2: Unlocking VP's Potential
1. **RAISE AWARENESS:** Organise seminars, workshops, and webinars to educate the screen industry about the environmental benefits of virtual production and real-time workflows. Demonstrators are needed showcasing successful adoptions. Consider Alignment with the AHRC-UKRI CoSTAR Network and National Labs. Incentivised training providers to support this awareness building.
2. **GREEN CERTIFICATION (THOUGH PUBLIC FACING):** Standardised system for certification should be considered that is audience facing. Consumer choice will play large part in wider adoption. Clearly identifiable icon or logo certifying sustainable benchmarks could greatly influence public engagement and corporate practice. Generate awareness among consumers, encouraging them to opt for content produced by eco-friendly practices (including virtual production workflows), giving audiences agency.
3. **PROMOTE SUCCESS STORIES:** Publicise stories, testimonials, and case studies of successful virtual production implementations that have helped reduce carbon footprints and greenhouse gas emissions, inspiring other companies to follow suit. Further field work and research would unlock new examples, but the publications need to move into the mainstream and be designed with a mainstream audience and mainstream media in mind.
Theme 3: Tech Barriers
4. **CARBON REDUCTION AS A COMPELLING REASON TO INVEST IN THE UK SCREEN INDUSTRY:** Greatly enhanced by the adoption of Virtual Production technologies. More accurate data and metrics supported through carbon calculators specifically designed for Hybrid Production. Market these USPs globally to attract large scale investment in UK based production.
Theme 4: Drivers of Change
5. **INDUSTRY CERTIFICATION:** Connected to the above with work already underway through key stakeholders in the sector is a B2B certification program that rates production companies based on their carbon footprint, thus incentivising them to adopt virtual production workflows to achieve better ratings.
6. **COLLABORATIVE PLATFORMS:** Facilitate collaboration between virtual production technology vendors and manufacturers, enabling knowledge exchange and accelerated innovation with respect to net zero ambitions.
7. **INVESTMENT IN R&D:** Encourage investment in research and development to produce more advanced virtual production technologies that will make it easier and more cost-effective for production companies to switch from traditional methods.
8. **INTRODUCE TAX INCENTIVES/REBATES:** Invest and encourage companies to engage in research and development of virtual production technology solutions. CoSTAR (AHRC) Network and National Labs will build strong infrastructure across the UK to support this activity over the next two years.
9. **CARBON CREDITS:** Offer carbon credits to production companies that fully adopt virtual production workflows, enabling them to offset their remaining emissions more cost-effectively. Newer more convincing and sustainable investments can be made by the industry to help offset some of the inevitable costs that will be required in production.
10. **STANDARD 'GREEN' SCORING METHOD** for Film Studios/Facilities or productions with rating system respected globally. Potential for a UK or British Kite mark for sustainable production. Those using Virtual Production Technologies will score significantly higher.

Theme 5: What's Stopping Us? Policy Suggestions
11. **GREEN PRODUCTION GUIDELINES:** Offer further funding support to established existing stakeholders in the green production area with funding to expand and develop existing understanding of virtual production in this regard. Development of guidelines for green production, that articulate the benefits of virtual production workflows.
12. **MANDATORY GREEN TRAINING:** Make it compulsory as a condition of funding for appropriate personnel from production companies/organisations to attend training programs or workshops focused on carbon reduction workflows where public money or tax incentives are involved in funding a production.
13. **EFFICIENT ENERGY USAGE:** Encourage and incentivise virtual production technology manufacturers to develop solutions that consume less energy combined with the use of renewable energy sources at studio facilities.
14. **MANAGEMENT OF DIGITAL WASTE:** Developing universal standards that enable re use of creative assets or LiDAR scans of environments for other projects. Reusing assets and finding ways to make these assets interoperable will significantly reduce the carbon impact of asset creation.
15. **POLICY INTERVENTION ON THE MANAGEMENT OF DIGITAL ASSETS CREATED AT CULTURAL HERITAGE SITES** for use in creative environments. Some regulation is likely needed to manage ownership, copyright and intellectual property rights of national heritage in the digital domain. (3D Scanning and LiDAR).
16. **DEVELOPING A FRAMEWORK FOR RAPID ADOPTION.** Building out a full strategy for the implementation of the technology and how to incentivise and encourage adoption is now required. This will require a working group and governmental support to fully unlock the UK's potential to be world leading in the reduction of the carbon footprint of productions. This could be driven by funding this research activity in the CoSTAR network.

3
Introduction and Context



3.1 BACKGROUND AND APPROACH

This report represents the culmination of extensive market immersion, applied research, and intelligence gathering conducted over a period of nearly three years to understand the ecosystem surrounding virtual production and its potential application. The author, in collaboration with Professor Frank Lyons MBE, is a co-founder of Studio Ulster, a large-scale 75000ft2 virtual production studio complex. This £72 million project, part of the Belfast Region City Deal, will establish a commercial virtual production studio complex with integrated Virtual Production university-led Research Innovation Labs Belfast Harbour Studios, Northern Ireland in 2024. The facility is a partnership led by Ulster University with Belfast Harbour Studios and Northern Ireland Screen. As part of the project development process, it was crucial to comprehend the wide-ranging implications of this technology, including its environmental impact, which played a key role in the successful business case.

3.1.1 The unique aspect of this endeavour is the cohabitation of various virtual production technologies, research labs, and innovation facilities within a single facility, located alongside a pre-existing world class studio complex capable of accommodating large-scale productions. To gain a comprehensive understanding of the sector, the author engaged in over 50 consultations with international companies over a span of two years. This took several forms from informal and private meetings with leading experts in industry to structured pre-market engagement surveys. The vast majority of the data collated is market sensitive at a critical junction for Studio Ulster's commercial business as of August 2023. Early on, it became evident that major production companies were interested in the environmental benefits of virtual production and its potential for reducing carbon emissions in their global operations. Some had not considered it but were very curious as to how this manifest. Many (Netflix, NBC Universal, Sony Pictures, BBC Studios, Sky Studios) have realised Carbon Reduction strategies working towards Net zero targets. VP now has the potential to support and accelerate these ambitious plans.

3.1.2 Film production companies are under increasing pressure from the public to engage in green and environmentally friendly practices commercially. This is due to several factors, including:

- → The growing awareness of climate change and the need to reduce greenhouse gas emissions.
- → The increasing popularity of sustainable products and services.
- → The pressure from investors and shareholders to adopt sustainable practices.
- → The desire to attract and retain talent who are concerned about environmental issues.

3.1.2 Specific examples of how film production companies are engaging in green practices include Netflix's commitment to net-zero carbon

emissions by 2022. (Netflix, 2021) or how Disney has pledged to use 100% renewable energy for its productions by 2030.

3.2 Literature Review An extensive literature review was also completed to inform this study, building on the work of others in the area such as Noonan's systematic review of related literature in 2020. The review focuses on currently published materials. This author acknowledges that the speed at which the VP industry is progressing, and the pace of technological development cannot be adequately reflected in printed materials even as recent as late 2022 or early 2023. The impact of generative AI is only now starting to emerge in written discourse around 3D visual effects and there is little written in an emerging area of scholarship about real-time production processes.

3.3 In the broader context of ongoing work in the screen industries, key stakeholders like the British Academy of Film and Television Arts (BAFTA) funded ALBERT initiative have identified four core areas responsible for around 80% of a production's total carbon use under scope 1, 2, and 3 emissions through case studies of various productions, these are:

1 Transport
2 Material use
3 Electricity use
4 Heating.

3.4 The technology stack employed in virtual production significantly influences the first three areas. Fuel consumption alone accounts for approximately 48% of emissions in 'tentpole' productions, with travel such as flying crew around the world and moving from one location to another contributing approximately 24%. Additionally, utilities play a substantial role in the overall emissions at circa 22% (Green Production Guide, March 2021). Our case study used in this report and carried out in our virtual production lab in York Street at Ulster University's Belfast campus correlates with other studies in the field, indicating a trend in findings that incorporating virtual production technologies in film or high-end television (HETV) production pipelines results in carbon reductions ranging from 20% to 50% compared to traditional production methods, and as far as it is feasible to track carbon consumption with current calculators and available data on associated manufacturing. In the UK, a recent report from the Creative Research and Innovation Centre by Prof Graham Hitchens (CRAIC, 2023) outlined the existence of 87 virtual production facilities (see full report here) at the time of publication of varying scales across the UK and Northern Ireland, primarily focused on training rather than commercial use. Current market trends will likely mean that many of these facilities will not survive unless they can create a sustainable ecosystem around them. More on this later.

3.5 The aim of the Paris Agreement is to limit global warming to between +1.5° C to +2°C. For this to be achieved, Europe has committed to reduce its carbon emissions by 55% by 2030 from the 1990 base line. In the context of the screen industries, it is important to understand the type and scale of the projects many of the studios using virtual production technologies are working on and how significant virtual production can be in reducing carbon use in film production. Studios offering AAA virtual production facilities to 'tent pole' productions operate in a global market. What is becoming increasingly important to these international production companies is their commitment to move to a net zero ecosystem for production. Many of the largest companies in the world have already announced plans to do so publicly such as Netflix, NBC Universal, BBC Studios, Sky Studios and Amazon Prime as reported in Entertainment Partners in April 2022. If the UK does not keep track with developments elsewhere in the world through equal or better offerings that can help these companies achieve their net zero ambitions, then it is likely these investments will simply move to countries where this can be achieved (BFI, September, 2020). In some cases, broadcasters and streamers will not comission content if companies do not comply with their net zero aspirations and those international production companies working in partnership or co-funded. ALBERT being one case in point for many of the key UK broadcasters they now require ALBERT certification and reporting. Some of the biggest production companies working in the UK currently include many North American companies such as HBO, Paramount, Sony, Apple, Amazon Prime, Warner and others. It therefore becomes critical to the screen industries success in the UK and Northern Ireland to engage in 'Green Competitiveness' (Fischer, 2011). This is quite a challenge as will be discussed in the context of increased use of technology, hardware and emerging technologies such as cloud-based computing, 5G and of course, rendering 3D assets and LED Volumes/ Video Walls.

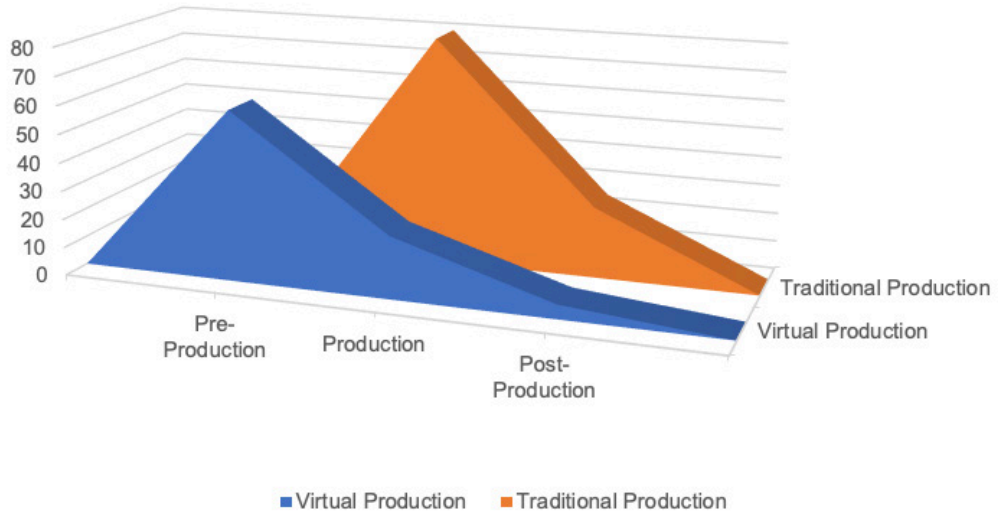
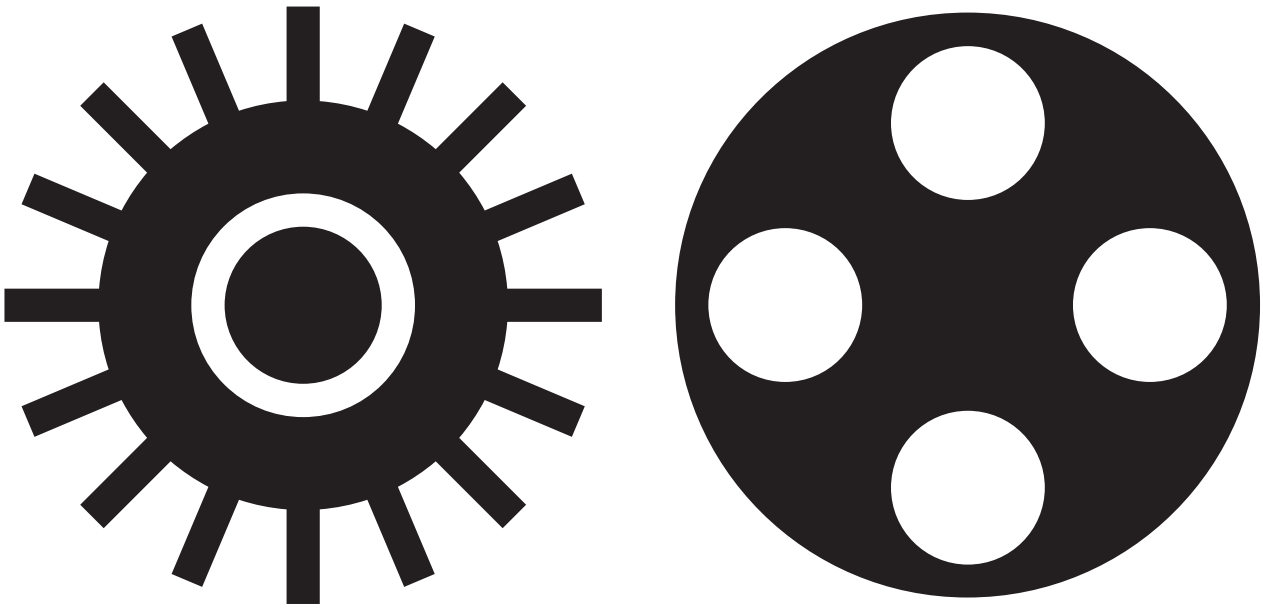


FIG 4. TIMING OF COST SPEND DISTRIBUTION ON TRADITIONAL V HYBRID VIRTUAL PRODUCTION WORKFLOWS. NUMBERS REPRESENTING £0-80K (TEST SHOOT-CASE STUDY ULSTER SCREEN ACADEMY-JANUARY 2023)

4
A Case Study: *A Thing Called Joy* (*Virtual Production Short Film*)



4.1 To enhance our understanding of the technology and prepare for the launch of Studio Ulster in 2024, the Ulster Screen Academy at Ulster University designed and installed a virtual production training and research facility on its York Street campus in Belfast, Northern Ireland. This £1.6 million investment, 210 Panel LED Volume and associated technologies was partially funded by the Department for the Economy in NI, aimed to support the university's ambition of introducing virtual production to Northern Ireland, levelling up our visual effects (VFX) industry, and increasing the competitiveness of our studio offerings in the region. The presence of our own Virtual Production Studio, including the first In-Camera Visual Effects stage or LED Volume in any university in the UK or Ireland, offered two significant advantages:

4.1.1. **ADDRESSING** talent shortages: Through industry consultations, we identified talent shortages in the sector, which pose a threat to its sustainability and growth. Northern Ireland's VFX ecosystem is relatively small, with little or no metrics available for the sub-sector. There is a global shortage of skills related to 3D VFX and virtual production pipelines. Training offered through The Ulster Screen Academy at Ulster University includes embedded sustainable practice and carbon reduction principles.

4.1.2 The VP Studio at Ulster University is also *an applied research and virtual production technology testing facility*: The facility provided the team, as researchers, with a controllable laboratory to test the technology, develop new workflow solutions, and gain an in-depth understanding of the advantages and disadvantages of virtual production through applied research. This also facilitated calculations and testing related to the carbon impact of these technologies used for the case study here.

4.2 VP represents the convergence between methodologies and technology solutions such as real-time rendering, world building in games engines, motion capture, 3D and 4D scanning, LiDAR, Photogrammetry, and other emerging technologies such as virtual reality (VR), augmented reality (AR), extended reality (XR), previsualization (Previz) and 3D environments to create a seamless blend of live-action footage and computer-generated (CG) content in real-time. Technologies to enable these workflows are available at Ulster University for testing. Bringing these solutions together into the university environment in Belfast enabled the project team for Studio Ulster to explore first-hand the challenges and benefits of this technology. The technology installed in Belfast is essentially a scaled down version of a large-scale LED Volume stage or In-camera Visual Effects Stages used in tent pole productions such as Star Wars, *The Mandalorian* (Disney). See Fig.6 below.

4.3 Virtual Production Volume stages can be configured in many forms project by project but often resembles a cave with walls made of seamless LED video panels or screens fed by photorealistic imagery from a game image or video server. By leveraging these advanced

technology sets, the author enabled Northern Irish filmmakers, animators and visual effects company Taunt Studios in Belfast to create an immersive and visually stunning short test film called *A Thing Called Joy (Taunt 2022).* Funded by Innovate UK the short experimental film enabled a commercial scale production with a budget of circa £80k in real terms including in kind support. This opened the opportunity to test and develop the VP workflow including applying a carbon calculator to understand the carbon usage in a scaled down facility. The short film project was the very first in-camera virtual production filmed on the island of Ireland using an LED volume.

FIG. 5 VIRTUAL PRODUCTION STUDIO FACILITY-ULSTER SCREEN ACADEMY AT ULSTER UNIVERSITY BELFAST 2023
IMAGE COURTESY OF ARMCHAIR AND ROCKET

FIG. 6 VP STUDIO II IN STUDIO ULSTER AT BELFAST HARBOUR STUDIOS. IMAGE COURTESY OF STUDIO ULSTER LTD

4.5 The project enabled our research team to track and explore the obvious carbon benefits of not travelling to location and other impacts such as power consumption as outlined earlier in this report. For our case study we explored different models of imagined delivery to recreate a controlled experiment in our VP Studio based on data gleaned from the production cycle. As much information as could be extracted was analysed using a carbon calculator.

4.6 Case Studio

4.7 Statistical evidence presented in many of the key carbon output reports related to the screen sector carried out on productions from around the world (see full literature review) to date draw roughly the same conclusion as the team in Ulster University; that using virtual production technologies has a significant impact on carbon use in film and broadcast productions in a positive way. Our tests in Belfast, where the power source is understood, its usage, staff travel and journeys averaged, times of powered up equipment recorded and rendering processes monitored and as far as possible recording as many elements of Scope 1, 2 and 3 GHC emissions as could be easily identified led us to draw remarkably similar findings when scaled up against larger studies internationally. See figures 8 and 9 above. Fig. 8 is a graph of findings made at Ulster University's VP studio in York Street on a modest budget of just £80k (Fig 4) then compare the findings in that graphic to those made on a large-scale production analysis by Quite Brilliant (Fig. 9). The corelations are notable when scaled up and this trend continues across previous studies available publicly at this time. The carbon

FIG. 7 A PRODUCTION STILL FROM A THING CALLED JOY-COURTESY OF TAUNT STUDIOS

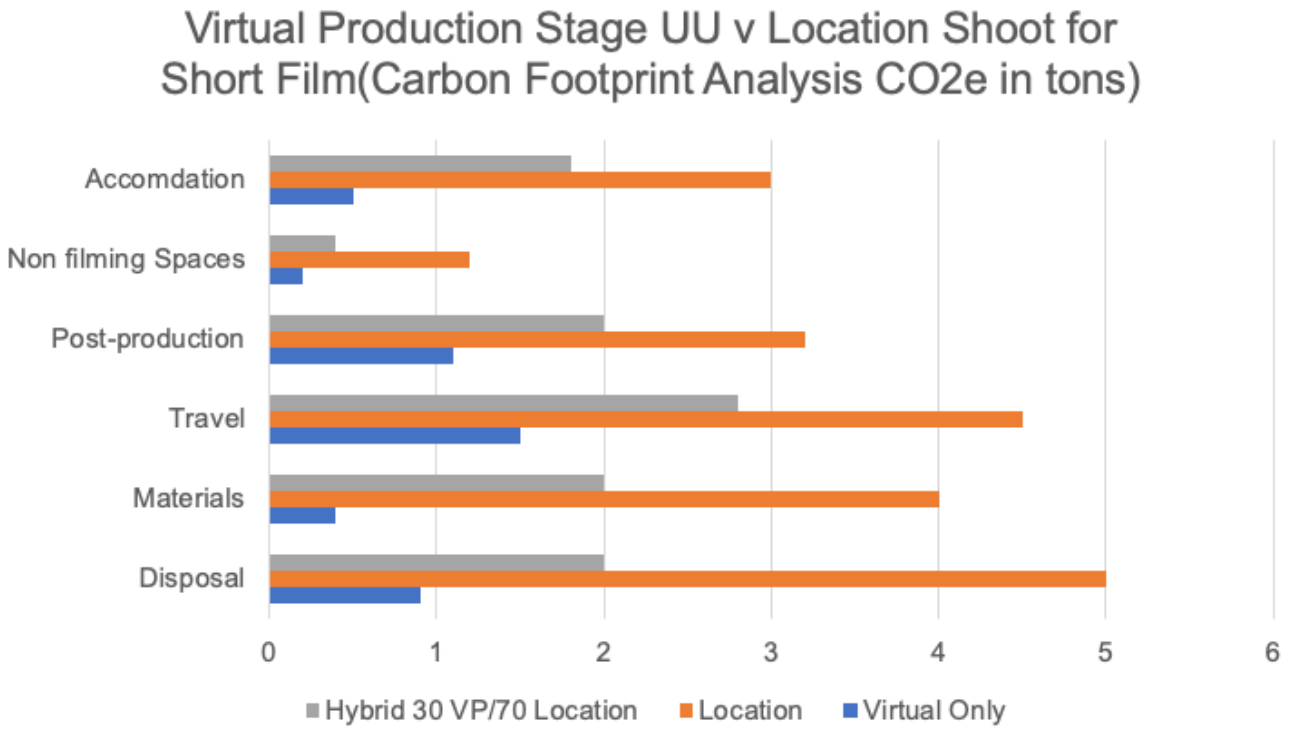


FIG. 8 COMPARE AND CONTRASTING VARIOUS SCENARIOS -100% LOCATION WORK AND 30% VIRTUAL PRODUCTION/70% LOCATION SHOOT FOR THE JOY OF NOTHING

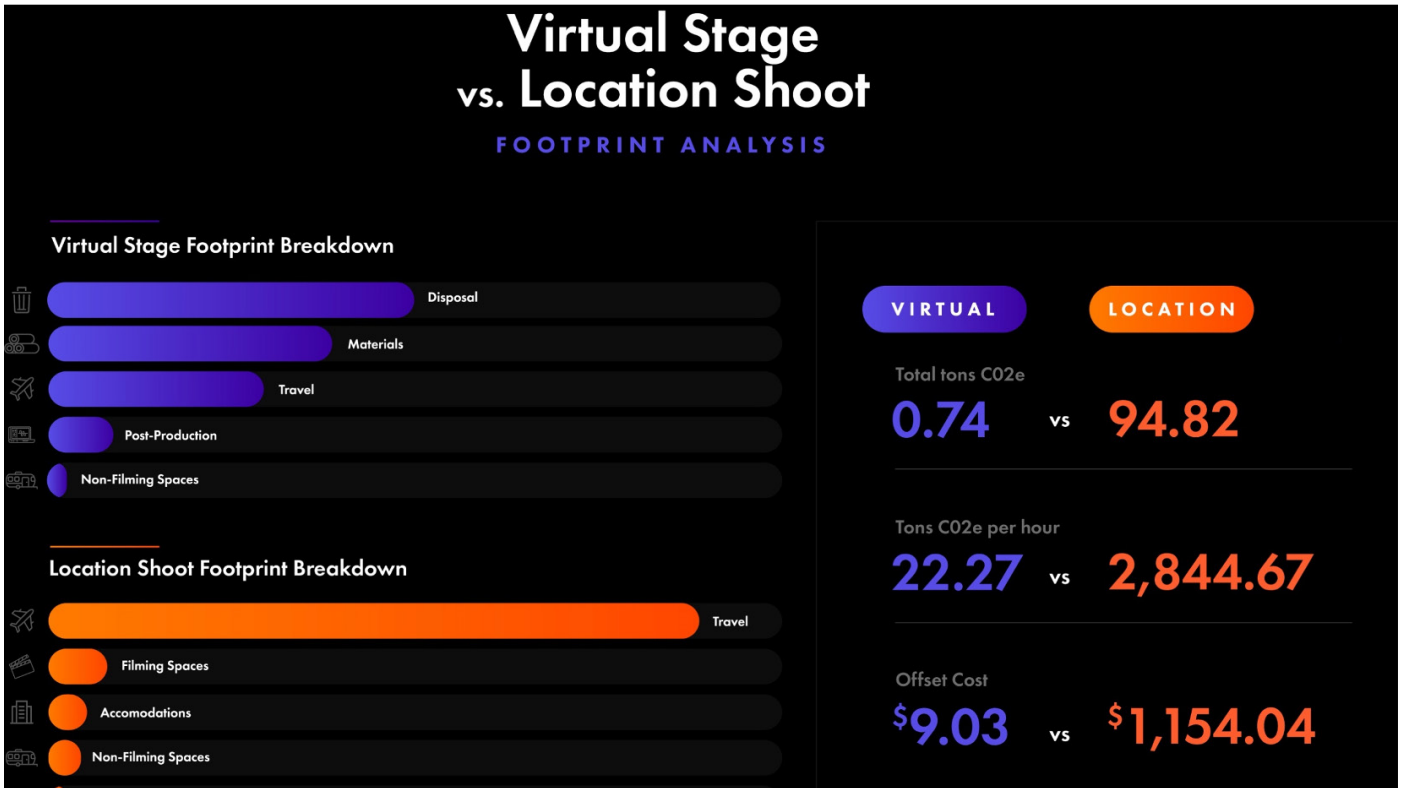


FIG. 9 DATA COURTESY OF QUITE BRILLIANT WITH ARTWORK BY ICON VIRTUAL

saving is significant though proposed here is that with more research and development investment could be improved or at least better understood to identify areas for improvement.

4.8 METHODOLOGY EMPLOYED/CARBON CALCULATIONS

In doing the carbon calculations for this short film case study we made followed the procedure outlined below considering various factors that contribute to carbon emissions during the lifecycle of the production of The Joy of Nothing:

- → **AIR TRAVEL**: The team measured the miles travelled by any crew members (in this case the directors were from London) and multiplied by an average emission factor for air travel.
- → **GROUND TRAVEL**: We calculated miles travelled in cars, vans, trucks, and other vehicles. Multiplied each by their respective emission factors. Complex and nuanced because not always possible to know if for example a commercial or private vehicle used diesel, petrol or renewable electric sources.
- → **POWER CONSUMPTION**: We listed all electronic equipment including lights, LED panels, computers, cameras, chargers, etc. Estimated the hours each will run and the watts they consume converted to kilowatt-hours. Then we multiplied the kWh by the carbon coefficient of the electricity source. Again, unknown precisely with regional variants and various power generation sources supplying the network in NI.

- → **ACCOMMODATION**: The team recorded if crew members or talent were staying in hotels or other accommodation, then factored in the carbon footprint of that style of accommodation as an average.
- → **PRODUCTION MATERIALS**: This included everything from the paper used in scripts to the sets, props, costumes, etc. Estimate the carbon footprint of creating and disposing of these materials.
- → **FOOD AND CATERING**: We consider the carbon footprint of producing, transporting, and preparing food. Meat-based meals generally have a higher footprint than vegetarian or vegan meals.
- → **WASTE PRODUCTION**: We calculated the amount of waste produced and its type (organic, plastic, hazardous, etc.). Used appropriate emission factors for each type of waste.
- → **POST-PRODUCTION**: Much of this was in energy use, so again, we calculated the kWh for editing suites, sound stages, etc., and multiplied by the carbon coefficient of the electricity source using various scenarios and different percentages of virtual production.

Once the emissions for all the individual segments have been calculated we collated and totalled each. Noting at the time that emission factors (like those for air travel, car travel, or electricity use) can vary based on region and source. Some of these factors can be sourced from environmental agencies or organisations that specialise in carbon footprint calculations though a databased specially for VP does not exist.

4.9 To be effective, we discovered that the calculator should be updated regularly as the production progresses, and efforts should be made to minimize the carbon footprint through sustainable practices of doing so.

4.10 In the context of our virtual production model (model used for production) the calculations made are too large taken together to include in this short report but can be summarised as follows

4.10 SUMMARY OF CO2 USE FOR JOY OF NOTHING

Travel
Air Travel: 1,500 miles, Emission factor for air travel: 0.2 kg CO2/mile
Car Travel: 750 miles, Emission factor for car: 0.3 kg CO2/mile
\{Emission}_{\{travel}} = (1500 \times 0.2) + (750\times 0.3)
\{Emission}_{\{travel}} = 300 + 225 = 525kg CO2
Power Consumption during production
Equipment uses 35kW*, equivalent to 10 hours/day for 6 days for prep, shoot and edit (includes LED wall plus additional equipment in studio-pre and postproduction
\ {kWh} = 35 \times 10 \times 6 = 2100 \{kWh}
*Emission factor for electricity: 0.5 kg CO2/kWh
\{Emission}_{\{power}} = 2100 \times 0.5 = 1,050kg CO2
Accommodation
5 crew members (travelling, this figure does not include local crew living at home) stay for 4.5 nights, Emission factor: 15 kg CO2/night
{Emission}_{\text{accommodation}} = 5 \times 5 \times 4.5 = 112 kg CO2
Production Materials
Emission factor (sets, props, costumes): 360 kg CO2
Food and Catering
Emission factor for 30-day production cycle:450 kg CO2
Waste Production
Emission factor for the waste produced over 30 days: 175 kg CO2
Post and pre-Production Power Requirements
Equipment uses 25kW*, runs for 8 hours/day for 9 days
\{kWh} = 25\times 8 \times 9 = 1800 \{kWh}
*Emission factor used for electricity: 0.5 kg CO2/kWh
\{Emission}_{\{post-production}} = 720 \times 0.5 = 900kg CO2

****Total Carbon Emissions****

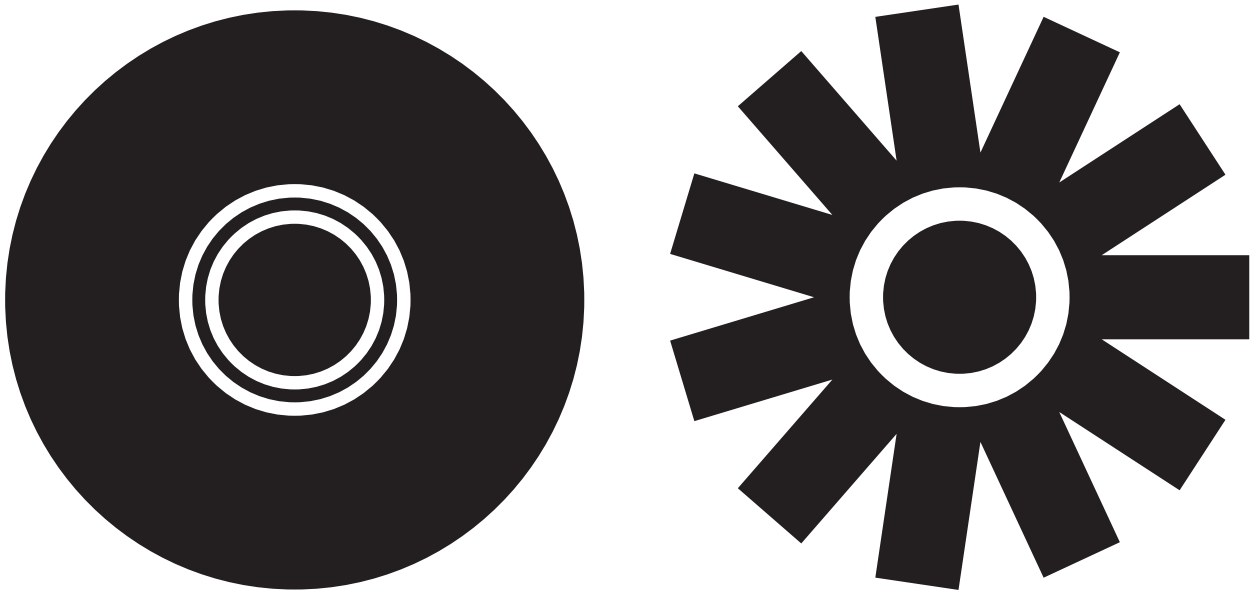
Total Emission KgCo2 = 525 + 1050 + 112 + 360 + 300 + 450 + 175+900

Total Emission = 3,872kg CO2

In this scenario, we estimated that the film production would have produced 3.87 metric tons of Co2 over the course of its production and post-production.

4.11 PROCESS: The Ulster University short VP film was shot over four days York Street with a local production company and employed 15 cast and crew travelling to and from set each day for crew. These were locally based in Northern Ireland with data captured on as many aspects of attributable carbon production as was possible. This included individualised mileage calculations for example at .45kg/mile. This then was modelled against the locations this film would have been shot on had it not been made in a Virtual Production entirely. Right away a set of challenges are obvious in that it is difficult to do these data calculations accurately for comparison when the film was only made once using a virtual production studio and ultimately not made again on location. The location calculations were devised in consultation with a highly experienced location manager and first Assistant Directors as to how the film would have manifested if shooting traditionally. Secondly an imagined shooting schedule for hybrid model combining a traditional process with VP techniques was created at 30% VP/70% traditional location-based shooting. This is not uncommon in large scale productions with 30% being the likely value trigger point for using the VP pipelines in large scale productions (Monika Chowdhary-Kuczynski VFX Producer and trainer at '*Stepping into Virtual Production*', Ulster Screen Academy, May, 2023).

5
Key Areas of Concern And Policy Drivers



5.1 *Harnessing Artificial Intelligence and Machine Learning (AI and ML) warrants exploration and further investment*. AI and ML are having an existential impact on real-time digital content creation for entertainment. Whilst the focus in the main has been on the impact these technologies may have on employment there are some very exciting opportunities to harness these technologies to create better, faster, more productive production pipelines in the creation of digital content in the virtual production ecosystem. We know from other studies that reducing render time, reducing travel and production time saves carbon (Green Screen Interreg Europe, 2021). Artificial Intelligence and Machine Learning (AI and ML) can and is impacting carbon reduction in content production already by speeding up processes and enabling new hyper-realistic world creation and textual generated images for use in VR, XR and VP. New automated and generative 3D asset creation processes have the potential to greatly reduce tedious aspects of asset creation or create efficiencies and automation in creative workflows not yet well understood. Noah Kadner outlines the key connections to VP is his article from June 2023 in LAVNCH Code. Research and development in this area of the creative industries is needed to fully understand the full potential of AI/ML on of carbon reduction but also the profound impact these technologies will have on the sector broadly.

5.2 *Understanding rendering and the full costs of data processing:* We need to better understand the complex digital ecosystem for digital content creation and the technology data transfer pipelines used in VP on premise and in cloud computing. Volume and costs of processing data are difficult to quantify or indeed track unless you are given access to these pipelines in some way. IT designed carbon calculators could help here and the associated growth of the 'Environmental Consultancy' sub sector. *It is likely we need to challenge any assumption that the Creative Industries or part thereof are carbon neutral or carbon negative in outlook*. What is not easily seen, is the volume of data required in the creative digital sector and the movement of this data internationally in the Cloud. This is highly relevant in the context of carbon use. Where the data is being rendered, stored, or moved through are all factors. To understand the carbon footprint, we also need to understand how these data centres are managed, secured, powered, or indeed located to fully calculate the carbon footprint. It may also be the case that other sectors are more advanced in their processes and thinking in this regard and learning from other sectors could and should be employed in the creative industries. It might also be the case the carbon footprint of a production is shared across different countries and parts of the world given the nature of the modern production process. Rendering animation in the far east for example, colour grading in London and film editing in Los Angeles are not uncommon workflows. Data must move between all these centres and is often duplicated for bi-lateral workflows.

5.3 National heritage comes under the spotlight in relation to VP and the management of vast stores of visual data. *The UK now needs to explore*

new policies governing the ownership and management of 3D or 4D volumetric scans of national heritage sites and other historical artifacts or national treasures in public ownership. VP technology is used to replicate the real world in the digital realm. Essentially the premise of the Metaverse but applied here to use cases in digital content creation for screen. New policies will be needed to protect ownership rights and establish a framework for preserving valuable national assets in future. In most cases it will no longer be necessary to bring a large 'unit base' of film crew on to a sensitive environmentally fragile location at a national heritage site where that crew could have access to or be encouraged to use virtual production pipelines. Using VP enables new workflows such as LiDAR scanning and Photogrammetry that could virtually remove risk and associated negative press if working in these locations in future.

5.3.1 The added benefit of this workflow being the preservation of national assets whilst at the same time featuring these location or artefacts on the big screen and unlocking an association to a high-profile film or drama franchise sustainably.

5.4 *Working in Cultural Heritage Sites*: Filming in sites of cultural heritage often adorned on our screens is becoming more problematic. This is of the utmost importance when considering protected natural wilderness and ecologically sensitive environments with attendant cultural heritage factors which have often been negatively impacted by industrial cinematic production. In this respect virtual production has agency. Whilst long establish is the role the medium itself has for eliciting an inspiring social change in environmentalism (Al Gore's seminal work 'An Inconvenient Truth', 2006 for example). Brodie (2020:674) says that 'Ruth Barton has observed in her essay on the questionable tactics used by both the Star Wars production and an array of state services (including the Irish Film Board) to film on the UNESCO world heritage site Skellig Michael, this sacrificing of public heritage at the altar of profit is widespread across Irish economic development (Barton 2019 307; see also O'Toole). This "devil's bargain" applies to both production and tourism.' Using digital twins in an LED Volume will still encourage screen tourism for example. The audience would not know for sure if the actors ever visited the location in real-life. Provided this can be well manged on the ground and does not drive uncontrolled access and bring further damage to the sites of interest there is no loss to using virtual versions of the real-world on screen.

5.5 In the context of a gathering storm of research relating to the environmental impact of the screen industry it is surely incomprehensible that governments will be able to circumvent regulations and protocols surrounding access to vulnerable ecological environments in the future. What remains then is an incentive to map these environments and use this resource as a measuring/monitoring instrument which can determine the real consequences of allowing access. Furthermore, the mapping of Skellig Michael using LIDAR

technology for instance "provided the opportunity to record the subtle morphological evidence of human activity on the landscape, a powerful tool to help archaeological investigators unravel the evolution and functions of historic sites using non-destructive methods" (Shaw and Corns 2011).

5.6 Public backlash towards film productions due to environmental concerns is a testament to the audience's increasing awareness and demand for sustainable practices. Here are a few instances where film productions faced significant criticism for perceived harm to the environment:

5.6.1 "Pirates of the Caribbean: Dead Man's Chest" (2005): The film faced backlash for allegedly damaging the fragile ecosystem of the Bon Accord Lagoon in Tobago. Reports alleged that the crew bulldozed a protected mangrove habitat to create a set. However, Disney countered the claims, stating that they had the necessary permissions and took measures to limit environmental damage.

5.6.2 "The Beach" (2000): The filming of "The Beach" starring Leonardo DiCaprio on the Thai island of Ko Phi Phi Leh caused controversy. The production was criticised for altering the natural landscape and causing ecological damage, particularly to the beach's sand dunes and vegetation. Following the film's release and the subsequent increase in tourism, there have been further concerns about the island's ecosystem.

5.6.3 "Doctor Who" (2014): The popular British television show was under scrutiny when it was reported that a special effects explosion during the filming at a beach in Wales had harmed a protected site. The explosion allegedly scattered fragments and sent some materials into a Special Area of Conservation.

5.6.4 "Mad Max: Fury Road" (2015): The film faced criticism for its impact on the Namib Desert ecosystem. Environmentalists raised concerns about potential long-term damage due to vehicle chases and other film-related activities on the delicate desert environment.

5.6.5 "Indiana Jones and the Kingdom of the Crystal Skull" (2008): The production faced objections from environmental groups and residents when they planned to shoot a scene in a protected part of the Amazon rainforest in Peru.

These instances highlight the importance of environmental considerations in film production. When there's a perception that a production has harmed the environment, it can lead to negative publicity and reputational damage. It's also worth noting that in some of these cases, the production companies took steps to rectify, mitigate, or clarify the situation, and have expressed their own side of the story. Nonetheless, public vigilance and concern play a crucial role in ensuring that film productions adopt sustainable and eco-friendly practices.

5.7 *The suggestion here then is that consideration should now be given as to how utilise digital replicas of locations on film (for use in virtual production studios or immersivity) and how these digital twins manifest in the real world.*

5.8 *Little attention has been given to the carbon reduction implications on an area or locale, national heritage site or random location becoming 'world famous' overnight* when featured in a new Netflix or Prime Series for example. The use of VP does not change that potential in fact the impact may be twofold:

5.8.1 VP can play a significant role in the preservation and access to these cultural sites in future and open significantly more opportunity to share previously inaccessible national heritage whilst protecting and preserving the site or artefact itself.

5.8.2 If managed correctly digital artefacts such as 3D scanned environments create new income streams to help preserve these sites through other sectors including tourism generation.

5.9 We now need to consider sustainability or existing infrastructure, the cultural life of the locale and community or the long-term implications of making locations famous. Whilst is offers a double-edged sword of increased travel and footfall, it can also provide much needed employment in areas of under investment (Yi, Zhu, Zheng et al, Fronters, June 2022)

5.10 *Legal loopholes on ownership of the intellectual property for 3D scans of a national heritage sites when used in digital content or on screen is unclear* with the law not having caught up to what is possible technically. This will likely require further analysis by experts in the area. Oruc, 2022 argues that 3D projects in some instances can lead to 'protectable outcomes under EU copyright law'. How this now manifests in the UK requires further attention.

5.11 The potential reuse through the *development of a lingua franca or international file format exchange standards* is in early development and is in the interests of large content production companies ultimately to do this work. Government has an opportunity to support and accelerate development of file preservation and exchange formats that make international working easier and that will offer new opportunities to exploit these assets in the best interests of the nation and ultimately *create opportunities to upcycle and use again* 3D assets for future projects or additional revenue. How we preserve these scans as a record in time of the location for research and analysis in future is also a benefit.

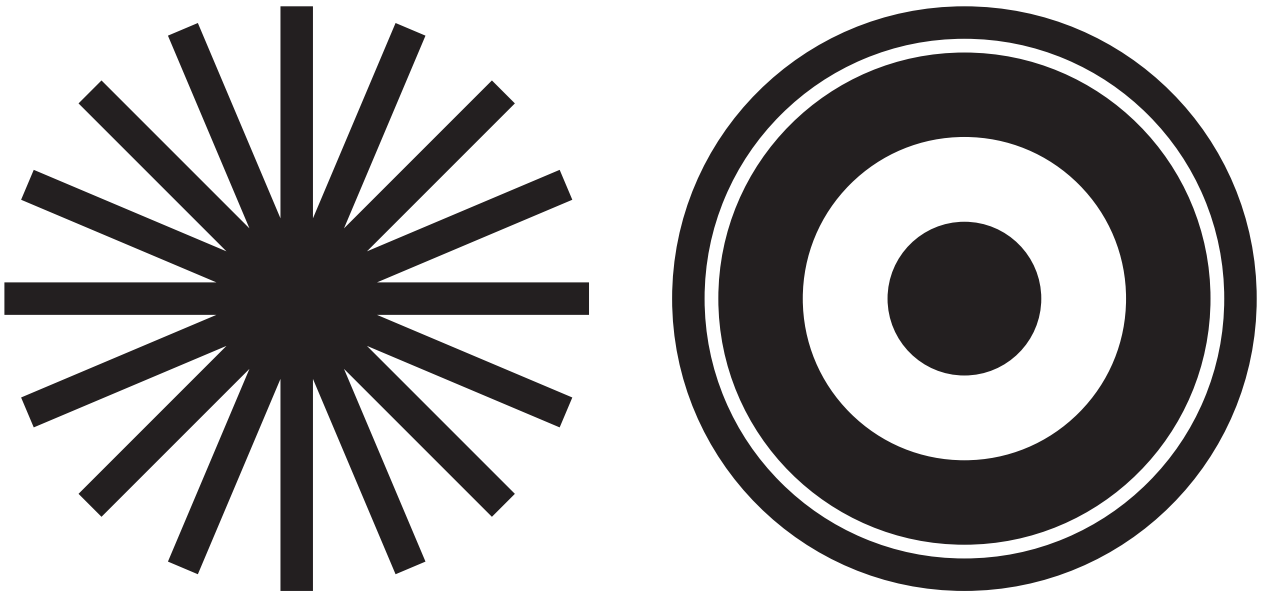
5.12 *Power outages and issues with 'brown outs or interruptions to power supplies in some areas are also now more of a concern and more common place in the context of global warming*. Current battery technology and associated costs are not a solution and cost prohibitive for VP Studios

primary operations given the consumption and amps needed. (Studio Ulster in Belfast needs maximally 1.6GW of capacity). However, many of the international studios are using their large studio roofs on studio complexes for solar arrays and battery walls to offset more generic energy costs within the building such as in costume and makeup areas, production offices etc. (e.g., Nant Studios please see Culvert City, LA Fig 11). Surprisingly many studios also mitigate the risk with standby diesel generators for Uninterrupted Power Supplies or UPS systems (Green Screen Report, Interreg, 2020). Diesel generators of course being a high source of carbon and other pollutants. Energy consumption in the screen industries is certainly not a new topic, Nadia Bozak's influential work (2011) raises the central theme of energy consumption in her comment on 'The Cinematic Footprint', with her claim that "cinema is intricately woven into the industrial culture and the energy economy that sustains it" (Bozak 2011: 1).

5.13 The question of obsolescence obviates the need for recycling/re-use infrastructure and resource planning that takes account of the economics of waste. This inevitably highlights disparities of conditions in the global north and south whereby redundant technologies are outsourced to developing countries who are expected to deal with the often-toxic implications of waste disposal. *In discussions with existing vendors in the sector, extending the life of LED Panels is possible. Often achieved by pushing the technology down the food chain*. For example, LED panels no longer suitable for large scale AAA productions likely because of pixel pitch (the density and resolution of the pixels on each panel currently at between 1.5/2.8mm in most facilities) is superseded or that better panels with higher dynamic contrast, better colour performance or refresh rates become available then broadcast might use but film would reject for high end studio work. These could also be bought and passed into the training environment for universities and colleges etc. It is worth noting that LED panel hardware originated in live performance work and that this is likely another good outlet for extending the use of LED panels to maximise the ROI and recycle the product for a long as is possible.

FIG. 11 SOLAR PANELS ON THE ROOF OF ONE OF NANT STUDIOS' VIRTUAL PRODUCTION SUITES IN EL SEGUNDO, LOS ANGLES AUGUST 2023.

6
Further Research Needs



6.1 Tracking data: As previously mentioned the movement of data is complex and the actual cost of rendering in this eco system in relation to carbon produced is hard to decern and almost unique in every production. *In the creative industries this movement of data alone could be the single biggest carbon generator for the industry, but we currently do not understand the scale of the issue*. How and where this activity happens is not always immediately clear even when talking to cloud based companies. (Gonzalez Monserrate, MIT Press, Feb 2022)

6.2 *Our current lack of understanding in relation to data movement and processes such as cloud-based rendering throws into question the rigour and analysis or comparisons currently being made with existing carbon calculators between traditional filmmaking and the use of digital environments and Virtual Production.*

6.3 *Adaptive reuse versus new builds needs further consideration when considering the whole life of a studio in the virtual production ecosystem.* The construction industry is keen to have a say in the matter also and it is a complicated area of discussion. The idea of repurposing old or existing buildings (often referred to as "adaptive reuse") versus constructing new, energy-efficient buildings is an ongoing debate in both the architecture and sustainable development sectors. Existing studies and sources that delve into the topic and relevant to the discussion here are:

1. **BREEAM AND ADAPTIVE REUSE:** BREEAM (Building Research Establishment Environmental Assessment Method) is a widely used environmental assessment method and rating system for buildings. Their standards and certifications shed light on the benefits of sustainable construction and can be used to compare the environmental performance of newly constructed versus adaptively reused buildings.
2. **ADAPTIVE REUSE:** Bullen, P.A. and Love, P.E.D. (2011) discussed the potential sustainable benefits of adaptive reuse. This paper presents the benefits and barriers of pursuing adaptive reuse as a sustainable option. (Bullen, P.A. and Love, P.E.D. (2011). Adaptive reuse of heritage buildings. Structural Survey, 29(5), 411-421).
3. **ENERGY USE IN RETROFITTED VS. NEW BUILDINGS:** A study by the National Trust for Historic Preservation's Green Lab found that it can take between 10 to 80 years for a new, energy-efficient building to overcome the climate change impacts of its construction, depending on the type and efficiency of the building it's replacing. (National Trust for Historic Preservation. (2012). The Greenest Building: Quantifying the Environmental Value of Building Reuse).
4. **CARBON EMISSIONS IN BUILDING CONSTRUCTION:** A report from the Global Alliance for Buildings and Construction, International Energy Agency (IEA), and the United Nations Environment Programme (UNEP) discusses the emissions associated with building construction and how they compare to operational

emissions. (Global Alliance for Buildings and Construction, IEA, and UNEP. (2019). 2019 Global Status Report for Buildings and Construction).

5 **CARBON CALCULATORS FOR THE BUILDING INDUSTRY:** The UK Green Building Council (UKGBC) has been involved in numerous discussions and initiatives regarding carbon assessments in the building industry, and they may have resources or tools that are relevant for evaluating the carbon impacts of construction versus adaptive reuse.

6.4 While these sources can provide foundational knowledge and insights, the specific comparison between repurposing existing buildings for use as virtual production studios and constructing new, energy-efficient ones would need closer examination.

6.5 LED PANEL MANUFACTURING: WHAT WE DON'T KNOW

A core gap in our current knowledge is created by not having full site of the manufacturing processes of LED panels internationally. These panels are 500mmx500mm video tiles used in LED volumes or ICVFX Stages.

> "The state of play regarding LED technology's GHG impact measurement is poor. As of yet manufacturers do not publish the Lifecycle Assessment of their products and, as it is an important parameter in the equation, we are missing a crucial part of the information." [Workflowers 2022: 24].

6.5.1 Wallflowers extrapolated some data about LED manufacturing by making some comparisons to the types of carbon impact better understood in similar technologies. Though their 2020 report highlights the knowledge gaps. Further, it is still a little unknown how long LED panels will last given VP is a nascent area of development though most vendors now suggest a life span of five years for virtual production installations installed new today with the ability to recycle the panels into the theatrical or broadcast use.

6.5.2 VP Screens of course are reusable literally thousands of times within that 5-year period. So ultimately to fairly distribute the manufacturing cost across those productions might require a longitudinal study attached to a large-scale VP studio. The report by Wallflowers mentioned previously suggests 'Making an assumption of a 40 kgCO2e/kg impact for an LED tile is probably conservative considering the manufacturing process and material use but it is a good starting point.' If this is the case and close to accurate, given it is the best figures we have right now, then a typical large scale virtual production studio using an in-camera visual effects wall on average has about 2000 panels. 2000x40kgCO2e/kg=80,000kgCO2e/kg for the manufacture of just one LED wall. This is a large figure taken in isolation but must be remembered how often this set up can be used over a period of 5 years before the LED panels will be fed down the

food chain to be repurposed for broadcast, live stages or training. The lifespan if correctly manged then could be 10 years which is how the panels are rated by the manufacturers also.

FIG 10. LED MANUFACTURING PROCESS-INFORMATION COURTESY OF ULSTER UNIVERSITY'S CREATIVE INDUSTRIES INSTITUTE

6.6 *Further research is required to map out carbon emissions regionally in energy creation or the CO2e per Kilowatt Hour of electricity cost.* This figure we know changes regionally, nationally and internationally. We are only just starting to understand that this CO2e figure alone can greatly change the market competitiveness of a studio if known in the context of client's investment decisions and net zero targets corporately. We must begin to map out these figures UK wide to fully articulate our true green credentials and for more accurate carbon usage models. Whilst the process has much integrity and rigour of carbon usage data is ultimately one reason why we cannot accurately pin down a range lower than 20% and 50% savings at present.

6.7 DIGITAL WASTE MANAGEMENT AND MANAGING SHARED IP

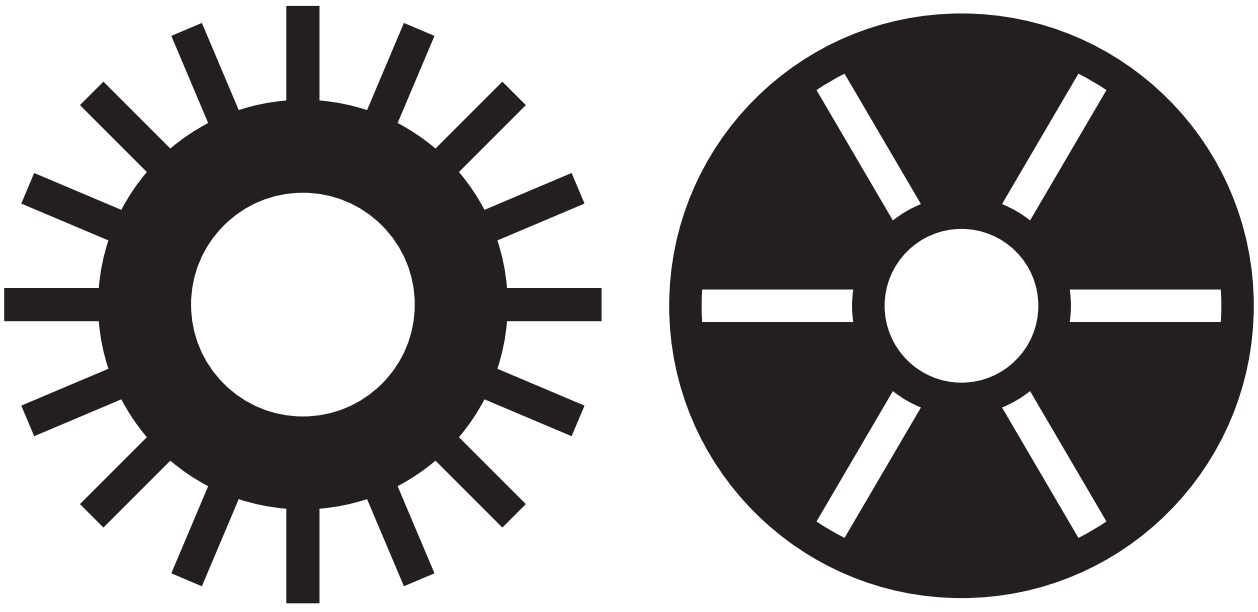
By now we can largely understand the methods for the reduction of waste in screen production with good advice available and training. The BFI/ARUP (2020), 'A Screen New Deal: a route map to sustainable film production' report espouses and endorses the PEACH, PEAR, PLUM regulatory practice model implemented by the Producers Guild of America (REF), and

seeks to adopt a regulatory regime suitable for working practices within a UK jurisdiction, while remaining cognisant of influential US commercial practices and operations. Albert and others offer very good models for reducing waste on productions in the material sense with certifications to reward those who follow the process.

6.7.1 CONSIDERATION TO BE GIVEN TO 'DIGITAL WASTE'. Nominally the 3D assets and worlds we create for each production. Often these digital virtual assets, scans of cultural sites and other locations are done for a single production or series and owned by a company. The ownership of these assets has not been well understood to date in relation to the state. Digital appropriation of heritage as copyrightable is not a sound principle to move forward according to Mubark, (2022). Further, digital NFTs and 3D printed models can be made once cultural sites are scanned. There are challenges on copyright and ownership in relation to generative AI engines also. The AI Act approved by the European Union in June 2023, will offer guidance on addressing issues around generative models. However, it is a seminal bill that will have profound impact on those who wish to make and sell content to the European market from the UK. Northern Ireland may have a notably different status in this regard with different access rights to the EU market and further work is needed in relation to differing trajectories for reaching net zero targets in both the European and UK markets accessible through Northern Ireland.

6.7.2 CONSIDERATION SHOULD BE GIVEN AS TO HOW DIGITAL ASSETS CAN ALSO BE RECYCLED IN THE CONTEXT OF UPCYCLING AND CARBON REDUCTION. Much of the current research is this area is based in university networked settings across Europe and North America. For example the Sauce Project who are exploring 'Smart Assets for re-use in Creative Environments' and then at the Academy Software Foundation (ASWF). These researchers and organisation are exploring the lingua franca needed for assets to be interoperable between projects, countries, software and company workflows.

7
Literature Review Key Insights



7.1 THERE MAY BE NO BIGGER AGENT OF CHANGE IN PRACTICE THAN THE CONSUMER OF THE BY-PRODUCTS OF VIRTUAL PRODUCTION IN ALL ITS FORMS. Building an acute understanding of what production practices do, might well drive consumer loyalty and attaches much greater weighting to the ethical and moral rationale for companies wanting to adopt these new technologies where appropriate to do so. Hunter Vaughan's exposé of 'Hollywood's Dirtiest Secret' (2019) was likely a catalyst for the fresh critical approaches to the challenge by Kääpä and others (Sørensen and Noonan, 2022), who foreground the environmental impact of production in the screen industry, a focus on 'localised cultural specificities' has inevitably opened concern over the diverse range of environmental impacts. Intentionally and unavoidably the approach of researchers associated with Vaughan is activist, not only in terms of the cause of environmentalism but also in respect of trans-disciplinary and inter-disciplinary trajectories of study and research. Consciously evoking tensions between qualitative and quantitative research methodologies, Vaughan/Kääpä and others in this milieux are critically aligned to a 'new' materialism (Bennett et. al 2010, St. Pierre, Jackson and Mazzei 2016, Lemke 2015) which promotes the production process as a relational field. Hence, the gap between critical academic research and the response of industry stakeholders has been a fecund area for the emergence of 'green' consultants, who offer advice and services to entities grappling with changing regulatory landscapes, some of whom have published important research in their own capacity, although questions of influence and critical independence will remain pertinent in the corporate world. This opens an important role for Government funded research to independently shape policy in relation to technology use in screen production.

7.2 IN RELATION TO THE REGULATORY LANDSCAPE, GOVERNMENT INTERVENTION AND THE IMPOSITION OF SYSTEMS OF CONTROL ARE CONSIDERED AS VIABLE AND PRACTICAL STEPS NEEDED TO CURTAIL OPERATIONS WHICH ARE DETRIMENTAL TO THE ENVIRONMENT. What we can say is that key stakeholders, some production companies, and broadcasters are already providing solutions to reducing carbon use in screen production. Threat of government intervention as a prompt for the industry to get its house in order, is a well-worn tactic, which some argue is no more than that (Bozak 2011, Cahill 2019). However, regulatory frameworks without teeth, captured by vested interests are regarded as 'paper tigers', the general sense of public discontent over a particular issue can, however, usher in a range of activities which requires that 'something must be seen to be done', regardless of its effectiveness (Sorenson and Noonan, 2022). The consumer therefore can be a key driver of change in carbon reduction in the creative industries but knowledge and understanding of the change needed and why, will require education, training and skills development with the public and the existing workforce.

7.3 Particularly notable is a study by Cineregio entitled, 'Green Screen Report 2020', which presents case studies and recommendations

that draw upon a wide array of innovative solutions to the problem of sustainable production modes and operations. The main thrust of the report emphasising the practicalities of recycle/re- use technologies and workflows and the auditing of environmental impact in quantifiable terms. Hence, even when considering VP, catering (the use of disposable plastics), energy consumption (inefficient and wasteful practices such as generator idling), are all areas that must also be included in the discussion of working to reduce carbon use in virtual production studio environments. Set construction/destruction/disposal and travel/accommodation costs are all common factors which should be included when considering a holistic view of sustainable production regardless of technology stack.

7.4 SOME ANSWERS CAN BE SOUGHT WITH REFERENCE TO THE RANGE OF CASE STUDIES WHICH THE CURRENT LITERATURE INVOKES AS PRACTICAL INTERVENTIONS *IN THE FIELD*. Statistical evidence tends to present comparative practice across the industry by defining a spectrum of 'commensurable' operations so that large scale 'tent-pole' productions can be measured against smaller scale independents. Although this is undoubtedly effective in the gathering and presenting of data relating to practice and operation, it fundamentally neglects the collateralisation of cost efficiencies on a cross industry basis and the discrepancies of commerce relating to the financing and resourcing of screen content and is a limitation of this report. Richard E. Caves (2000) addresses the problem of over investment in what he terms 'the nurture of Ten-ton Turkeys' by the creative industries, where "onlookers still remain baffled by the sums of money sunk in projects that ex post seems piteously inept" (Caves 2000: 136). Caves points out that the lack of certainty in terms of commercial success for a project and the reliance on collaborative networks which are inherently precarious give rise to conditions whereby contributors depend upon the terms of their contracts and the monitoring and supervision of these, may act to further personal interest by going along with processes which are patently not working out. Caves observes that this can be exacerbated by the kind of charismatic leadership which is common across the creative sector. This 'if it's not broken...' mantra often stands in the way of ushering in new innovative working practices in the face of the risk appetite of investors to take chances on new production practices.

7.5 Bozak's insistence that screen production processes should be grounded in sustainable practice from the bottom up, implies a reconsideration of the infrastructure of the industry which takes account of collaborative mutualism and reciprocity in a social sense as well as a sectoral sense (Bozak 2011) and ultimately a hidden challenge to adoption of these new practices.

7.6 An examination of current policy throws up gaps and opportunities which could incentivise and consolidate the potential of VP technology to greatly reduce the carbon footprint of large-scale production companies. However, what is clear from the literature is that this is

an industry weary of government policy and the threat of government intervention (Bozak, 2011, Cahill 2012) yet paradoxically depended on policy for incentives to drive FDI investment for foreign production companies at scale into the UK portfolio.

7.7 With Europe and the Paris agreement in mind the UK needs to be cognisant of our market position. We need to perform on par, with studio offerings elsewhere or be much more 'environmentally competitive' (see The Global Competitiveness Report-World Economic Forum, 2019 or The Green Finance Strategy-Department for Energy Security and Net Zero, 2019) when compared to other parts of Europe and North American. It is likely this 'carbon consciousness' that of large-scale producers will play an ever more important role in the decision-making process to locate and invest in productions in the UK. A VP company in the UK who can clearly articulate their carbon impact where favourable will then have a commercial advantage over rivals locally and internationally.

7.8 A standard carbon footprint scoring method for film studios/facilities related to virtual production, using new technologies such as 3D facial scanning studios, LED volumes, Motion Capture and other emerging technologies is needed.

7.9 The screen industry, which has regarded itself a being at the forefront of (r)evolution in commercial, cultural and technological terms, has conspicuously not kept pace ecologically speaking. A raft of reports, research papers and case studies have emerged in recent years which have been stridently critical of the screen industry's ecological deficit (Ashe 2019, Bigger Picture Research 2020, BFI/ARUP 2020, Cahill 2019, Hu, Xu, Tong & Razi 2022, Kääpä 2022, Lopera-Mármol and Jiménez-Morales 2021 Marks 2020, Meilani 2021, Sørensen and Noonan 2022, Vaughan, H., 2022, Workflowers 2022).

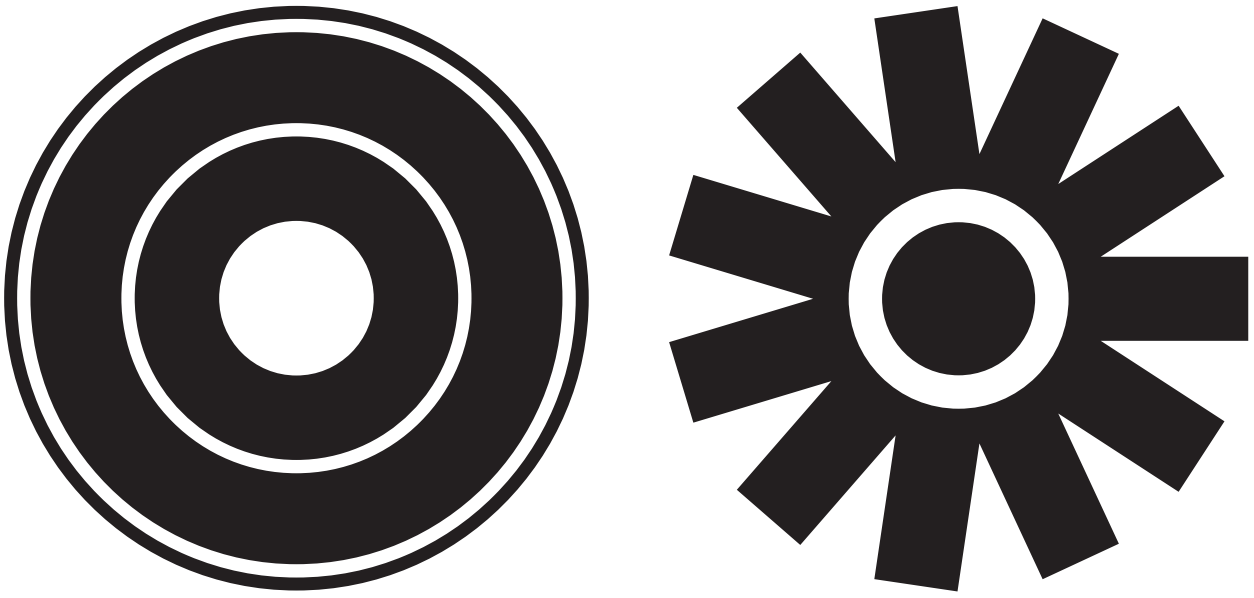
7.10 Inge Sorenson and Catriona Noonan (2022) appraising the efforts of national screen industries in terms of policies and power differentials, call directly upon media scholars to *develop a critical lens* so that commitments to green strategies are gauged in terms of deliverability, given that the industry is, "underpinned by highly polluting and wasteful practices and is a significant contributor to climate change" (Sorenson and Noonan 2022: 174).

7.10.1 Sorenson and Noonan also draw attention to industrial, structural and policy obstacles which inhibit the ability of the film and television sector to meaningfully respond to the practical challenges of this pressing area of policy concern (Sorenson and Noonan 2022: 172), asserting that contributing literature has over-focused upon representational elements of climate change as media content, while the impact of production processes have ostensibly been relegated to a peripheral position in the discourse (Sorenson and Noonan 2022: 173). A further disconnect between

STEM related research approaches and power/policy alignments in the screen industries which influence how impact is measured, it can be argued, renders much of the statistical evidence opaque or at worst, contributes to a form of *greenwashing*:

> "Green policies which are developed in isolation from other screen policies (such as around training, employment and co-production incentives) are unlikely to gain traction or secure meaningful change. Therefore, one of the main challenges for the screen sector will be how it balances the demands of environmental responsibility with market-based logics, the cultural rationales for national cinema and sustaining professional livelihoods in the sector." (Sorenson and Noonan 2022: 177)

8
Conclusion



8.1 Highlighted in this report are gaps in our knowledge and understanding in the context of having a deep understanding of Virtual Production's role in the reduction of carbon in screen production. What we can say for sure is that Virtual Production is a production methodology that will reduce carbon use in film production. The range for this reduction runs from approximately 20-50% percentage depending on how it is deployed but we need better data to enable more rigorous calculations. There is much work to be done to increase the likelihood that the UK will remain as one of the leaders in Virtual Production globally. Not least of which is how we now promote our virtual production stages in terms of their green credentials.

8.2 The UK needs methodologies to enable us to get accurate assessment and outputs for each of the VP facilities working in the UK. The numbers game where favourable, will be an important negotiating tool, not just in the board room and contractually, but also when attracting FDI and increasingly with a corporate responsibly that is driven by audience trends.

8.3 There are complex carbon calculators in play already and other calculators in related industries where combined, with the work of key stakeholders in the Screen Industries might lead to world leading solutions for tracking the full carbon footprints more easily in virtual production technology stacks. The glaring gaps in our knowledge are for example the carbon costs to manufacturing the LED based technologies, to the regional variations in costs of energy and its carbon impact. By cost I mean not just the financial but also the CO2e/kg against a KW of electricity drawn down from the network. Drawing together much of the analysis and thought presented in this extensive report enabled recommendations on policy gaps, gaps in evidence and inflection points in the nascent sector. These are framed in the context of potential policy levers and where intervention should be explored further.

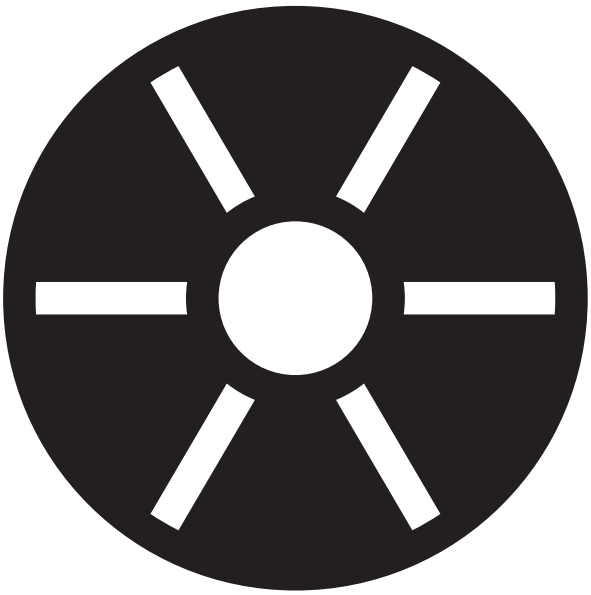
8.4 Recommendations will also highlight areas of further research and some suggestions as to how this can be achieved pragmatically. Given the scale of the endeavour and the complexity of the problem it would be overly ambitious to attempt to investigate all aspects of production and consumption and the myriad twists and turns of culture as commodity based upon accumulative principles of resource capture, exploitation and waste. Therefore, this report has focussed on drawing attention to the practical implications facing a new area of the screen industries still largely not well understood by much of the industry itself, let alone by wider policy makers. This is not to avoid drawing conclusions which might invoke the larger philosophical, economic and ethical/legal frameworks and discourses. The report endeavoured to focus our concerns on the practical ramifications of making an intervention to encourage wider adoption of VP. It has demonstrated that whilst there is more work to be done, virtual production is indeed

a technology and methodology combined that will play a significant role in reducing the carbon footprint of the screen industries and can support ambitious net zero targets going forward.

8.5 FUTURE RESEARCH NEEDS

1. Research funding is needed in the recycling and reuse of digital assets. Much is made of the material world being reused or upcycled but the same is becoming technically possible in the digital domain. The research is needed to explore and support the implementation of standards for a nascent sector that will increase interoperability and support arching of same.
2. Research is needed to fully understand the carbon costs associated with manufacturing LED technology stacks and disposal.
3. Further Research to develop ever more accurate Carbon Calculators is required. This could be achieved using living labs. Working alongside the CoStar network and for example located in Studio Ulster would provide real-world test cases that could be tracked over multiple commercial use cases by embedding researchers in the Innovation lab at Studio Ulster.
4. Working through energy equations for regions in the UK and ultimately building a cost-based analysis tool that will provide accurate answers on energy use and the CO2e/kg per kilowatt of electricity used in these facilities will provide more accurate data for assumptions to be made.
5. Consumer testing and response testing to visualised data comparisons in relation to traditional production costs versus production costs in carbon emissions terms of hybrid productions.
6. Consumer choice testing in relation certification and what behaviour changes can be achieved with the application of both knowledge and certification in consumption of content.

9
Glossary of Terms



Here is an extensive glossary of terms related to virtual production, virtual reality (VR), extended reality (XR), 3D world building, volumetric scanning, LiDAR, previz, simulcam, motion capture, augmented reality (AR), and real-time production pipelines for film, television, games, and animation production:

1. **3D MODELLING:** The process of creating digital three-dimensional representations of objects or environments using specialised software.
2. **VIRTUAL REALITY (VR):** A simulated environment where users can interact with and manipulate digital elements using specialized headsets (HMDs such as Meta Quest II) and controllers. In a virtual production context, VR allows filmmakers to scout digital locations, preview scenes, and even block out camera movements before shooting begins. It also aids the design process and collaboration of the environments required for use on LED walls. Environments once built in 3D software can be used in many ways including as VR worlds.
3. **HAPTICS:** The technology that enables users to feel tactile sensations or feedback in virtual environments, often using gloves, controllers, or suits.
4. **HEAD-MOUNTED DISPLAY (HMD):** A device worn on the head that includes a screen or screens to display virtual or augmented reality content, providing an immersive visual experience.
5. **INTERACTIVE LIGHTING:** Real-time lighting that dynamically adjusts in virtual environments to mimic real-world lighting conditions and enhance the sense of realism.
6. **KEYFRAME:** A specific frame in an animation sequence that represents a significant pose or position change. Keyframes are used as a reference for generating the in-between frames.
7. **LIDAR:** Light Detection and Ranging is a remote sensing technology that uses laser pulses to measure distances and create detailed 3D representations of environments or objects. It is often used in virtual production and 3D world building for accurate scene capture.
8. **MOTION CAPTURE:** The process of recording and translating the movements of real-world actors or objects into digital data, often used to animate virtual characters or objects.
9. **PHOTOGRAMMETRY:** The process of capturing real-world objects or environments using multiple photographs to create accurate and detailed 3D models.
10. **PREVISUALIZATION (PREVIZ):** The process of creating rough visual representations, often in 3D or 2D, to plan and visualize the look, layout, and timing of shots before production.
11. **REAL-TIME RENDERING:** The process of generating and displaying computer graphics in real-time, allowing for immediate feedback and interaction in virtual production.
12. **RIGGING:** The process of creating a digital skeleton or control system for a 3D character or object, enabling animators to manipulate and animate it.
13. **3D SCANNING:** The process of capturing the shape and details of real-world objects or environments to create accurate digital replicas.

14 **AUGMENTED REALITY (AR):** The integration of digital content into the real world through devices like smartphones, tablets, or AR headsets. AR can be used to provide filmmakers with real-time on-set visualizations of CG elements in proper scale and context, which can aid in framing and shot composition.

15 **SIMULCAM:** A system that combines real-world footage with virtual elements in real-time during filming or production, providing visual reference for actors and helping directors visualize the final shot composition.

16 **SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM):** A technology that allows devices, such as VR headsets or smartphones, to map and track their position in real-time within a given environment.

17 **VIRTUAL CAMERA:** A digital camera within a virtual environment or virtual production setup that allows filmmakers or

18 **VIRTUAL PRODUCTION:** The use of real-time technologies, such as virtual reality, augmented reality, and computer graphics, to create and capture elements of a film, television, game, or animation production in real-time employing games engines.

19 **VIRTUAL REALITY (VR):** An immersive technology that creates a simulated environment or experience, typically using headsets or HMDs, providing users with a sense of presence and interaction.

20 **VOLUMETRIC SCANNING:** The process of capturing the shape, appearance, and movement of real-world objects or people in three dimensions. It often involves multiple cameras or sensors to create a detailed representation.

21 **ANIMATION:** The technique of creating the illusion of movement through a sequence of static images or frames.

22 **EXTENDED REALITY (XR):** An umbrella term that encompasses both VR and AR, as well as any other immersive digital experiences blending real and virtual worlds. XR technology can be adapted to create dynamic sets, displaying changes in lighting or environmental elements in real-time for more accurate shot planning and execution. Think here of the BBC's 2020 use case from the Tokyo Olympics. Their studio replicated a roof top apartment building looking out over Tokyo but was in fact an extended reality studio in Salford.

23 **ASSET:** Any digital object, such as 3D models, textures, animations, or audio files, used in virtual production or XR experiences.

24 **PREVISUALIZATION (PREVIZ):** The process of creating rough animations or visualizations of scenes prior to shooting. Previz allows filmmakers to plan and visualize complex scenes, identify potential issues, and optimize the creative decision-making process. These visualizations can be particularly beneficial when working with CG elements or planning visual effects. More recently these previsualisations are building rendered using game engines such as Unreal Engine.

25 **AUGMENTED REALITY (AR):** A technology that overlays digital content onto the real world, enhancing the user's perception and interaction with their environment.

26 **MOTION CAPTURE (MOCAP):** A technique used to record the movements of actors or objects, converting them into digital data that can be

utilized to create CG animations or digital humans. Motion capture allows filmmakers to bring realistic and dynamic performances to even the most fantastical digital characters, improving the emotional depth and believability of the final product.

27 **AVATAR:** A digital representation or embodiment of a user in a virtual world or VR experience.

28 **REAL-TIME COMPUTER GRAPHICS:** The use of powerful game engines like Unreal Engine or Unity to render digital content in real time. This technology not only allows for instantaneous feedback on lighting and effects but also lays the groundwork for other virtual production technologies like LED wall stages. 3D worlds can be made available with parallax in camera for live in-camera recordings. These video wall set-ups are called In-Camera Visual Effects Stages ICVFX or LED Volumes by industry and if we refer to fig 1.3 below you will see a typical set up of a large-scale facility.

29 **CHROMA KEYING:** A technique where a specific colour (usually green or blue) is replaced with a different image or video during post-production, often used for compositing virtual elements into live-action footage.

30 **DEPTH OF FIELD:** The range of distance in a scene that appears in focus. It is used to create a sense of depth and to draw attention to specific objects or characters.

31 **GAME ENGINE:** Software that provides tools and frameworks for creating and running interactive computer games or virtual experiences.

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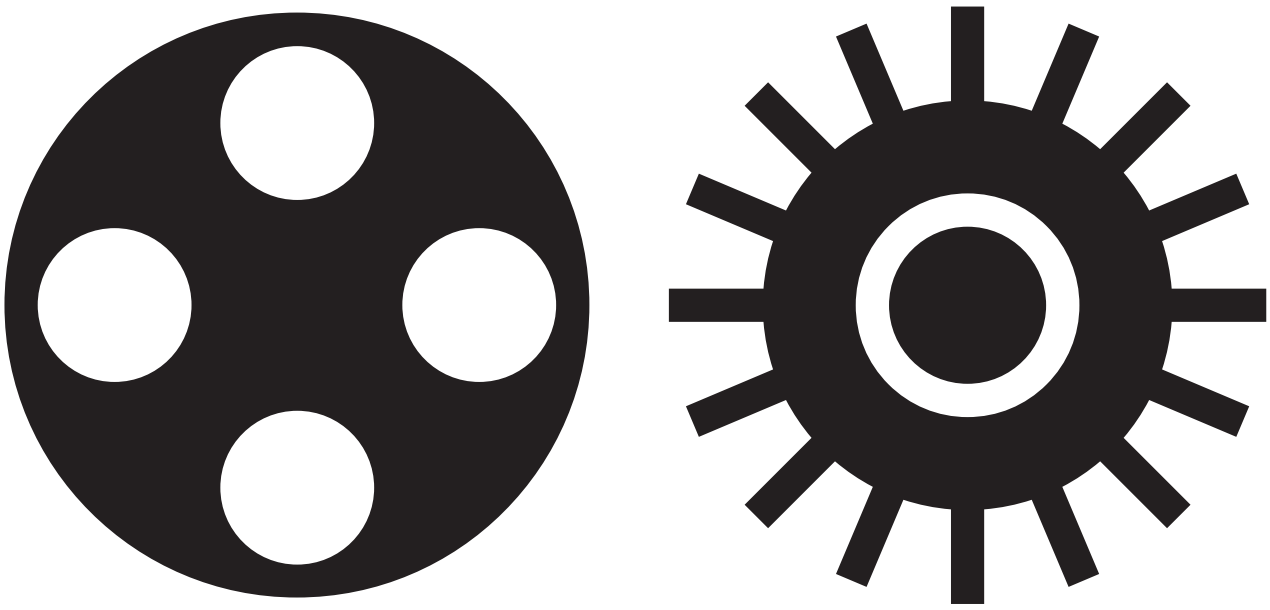

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→ Virtual Production (VP) is an umbrella term for an emerging group of

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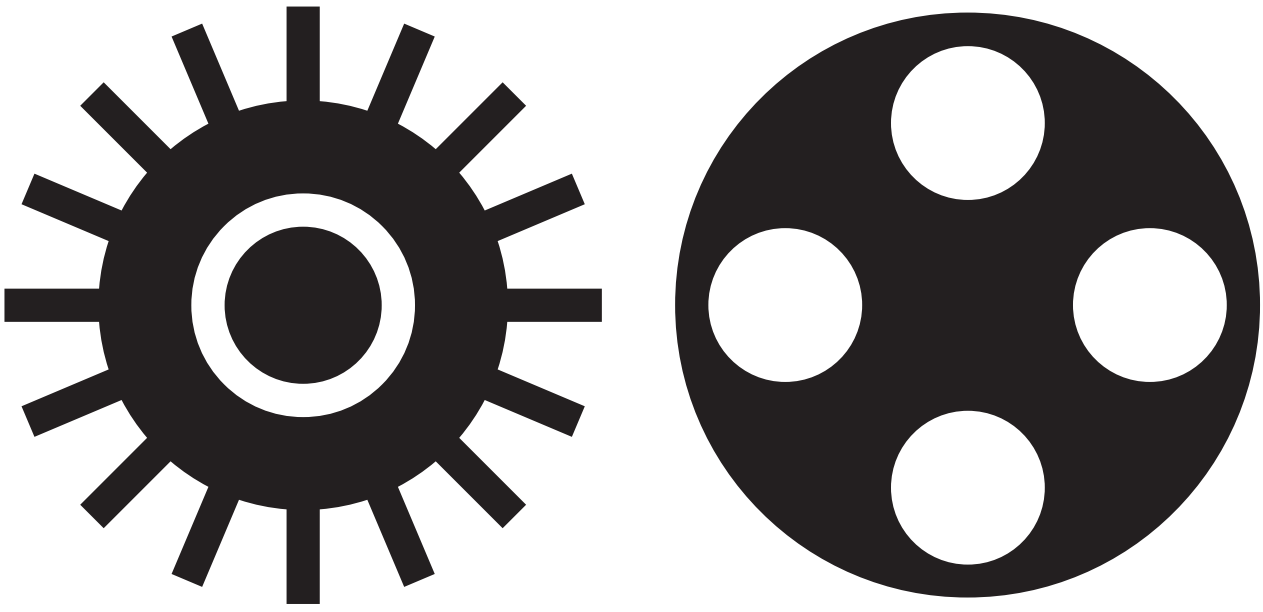
One Page Briefing Summary



real-time technologies revolutionising the Film, Broadcast, Animation, Games, and Immersive Sectors.

→ Utilising advancements in computer graphic rendering technologies, we now see unprecedented convergence in the screen industries.

→ VP methodologies combined with game engine software now make it possible to recreate our universe in the digital domain virtually and on large 'LED Volume' sound stages for film production. This meeting of the physical and digital brings new possibilities, challenges and of course opportunities for the UK to lead the sector in an emerging and nascent space.

→ VP technology can greatly reduce the carbon footprint of this fast-growing screen sector. In film production alone this can be between 20% and 50% in current large scale hybrid productions with further efficiencies possible with more research and development investment to push savings higher.

→ Building towards Net Zero film content production should be in the minds of all involved in a dynamic growth sector but critically it will become a deciding factor in large productions opting to invest in film and digital content production in the UK. Given the ambition of large-scale production companies to reach net zero targets internationally we must keep pace.

→ There are new challenges and new approaches, and policy interventions are needed if the UK is to remain one of the most successful and sustainable production ecosystems globally.

→ Building awareness with the public about green practices in production should not be underestimated as an agent for change.

→ Green Production Certification with standardised models would build confidence in investors and audiences, accelerating adoption.

→ Incentivising companies to use greener production methods and in particular virtual production would accelerate VP adoption in the market.

→ The workforce in the main are not yet ready for these developments with significant skills gaps identified that will be a critical success factor as the technology is adopted worldwide.

→ We now need to build in incentives to move to renewal energy where virtual and real-time rendering processes are used. These facilities are significant energy users and a standard for grading carbon efficiencies should be developed with support given to existing agencies in the field e.g., ALBERT

→ We need working groups in the creative industries in relation to the existential impact of artificial intelligence and machine learning will have on digital content creation in real-time and our early understanding that AI and ML will could play a significant role in reducing carbon use in this screen sector.

→ New policies on ownership and management of 3D scans of national heritage sites and other national treasures or artifacts are needed to protect ownership and IP. The environmental impact of this is not well understood yet.

→ The impact of featuring locations and regions in large-scale high-

profile productions even if virtual may need impact assessments done in advance.

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