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Greening the Audiovisual Sector: Towards a New Understanding through Innovation Practices in Wales and Beyond

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Abstract: Despite efforts towards reducing the negative environmental impact of the audiovisual sector, sustainability remains challenging. In this paper we address environmental sustainability in the Welsh audiovisual sector through the lens of green innovation. The mixed method study combines quantitative research measuring the adoption levels of green innovation inside businesses with qualitative analysis of selected case studies of green innovation. In doing so, the paper explores the extent of developing green innovation, as well as how research and development (R&D) as a specific roadmap to innovation leads to different forms of innovative outcomes. Based on this evidence, we propose an extended framework for considering green innovation in the audiovisual sector, one that differentiates between solution-driven, content-driven and mindset-driven innovation. By providing evidence of the extent and nature of green innovation in the audiovisual sector, the paper makes an important contribution to the underexplored field of green innovation research.

Keywords: green innovation; Welsh audiovisual industry; green innovation frameworks

Citation: Lupu, R.; Komorowski, M.; Lewis, J.; Mothersdale, G.; Pepper, S. Greening the Audiovisual Sector: Towards a New Understanding through Innovation Practices in Wales and Beyond. *Sustainability* **2023**, *15*, 2975. https://doi.org/10.3390/su15042975

Academic Editor: Luigi Aldieri

Received: 9 December 2022
Revised: 2 February 2023
Accepted: 2 February 2023
Published: 7 February 2023

1. Introduction

A gradual but growing awareness of the audiovisual sector's negative environmental impact has driven some studios, production houses and suppliers to consider practices for becoming more resource-efficient [1]. More recent developments include the emerging role of the eco-manager and the introduction of green consultant micro-credentials [2]. These are small but positive steps towards mitigating the sector's impact on the environment. On a more systemic level, trends like 'green shooting' [3] are beginning to encourage the industry towards more integrated approaches to sustainability, promoting environmental awareness and actions across all stages of audiovisual production (pre-production, production, and post-production). It aims to provide a systematic overview of how the use of technologies, the setup of production processes and the action and practices of staff on set can contribute to reducing the sector's negative environmental impact. These developments highlight the complexity behind a systemic shift towards a more environmentally aware sector [4].

Overall, however, research suggests that environmental practices remain challenging for an energy-intensive and hierarchical audiovisual sector [5]. In 2011 the worldwide audiovisual sector accounted for 1 m tonnes of CO_2, of which a quarter was directly related to filming (transport and electricity being among the two main causes) [6]. Despite its continuous efforts to reduce emissions [7], the audiovisual industry has remained among the most polluting sectors, driven first and foremost by unsustainable film production practices [8]. According to Eurostat data [9], in 2021, the audiovisual sector at European Union level has registered 2.3 m tonnes of greenhouse gases, representing an increase of 3.6% on a year-by-year basis. Considering that during 2020–2021, productions were drastically reduced if not completely halted due to COVID restrictions [10], the increase in emissions of the sector demonstrates the strong impact it continues to have on the environment. The situation in the British audiovisual sector is not much more encouraging either. Latest Eurostat data available (before Brexit) [11] confirms that the UK audiovisual

sector accounted for 9.2% of the total greenhouse gases produced at EU level (2019), which is slightly more than in 2018, when it accounted for 9% of EU-level emissions. CO_2 emissions also remain high. An hour of TV produced in the UK, for example, generates the equivalent of 5.7 tCO2e [12], which is more than a passenger vehicle generates over an entire year (4.6 tCO2e). To put it another way, an hour of TV is equivalent to an hour-long journey of thousands of cars. The carbon cost of blockbuster films is especially damaging, generating 150–250 times the level of an average hour of TV—the equivalent of the amount of CO_2 absorbed by 3700 acres of forest in a year [13]. Much of these emissions are attributed to energy consumption and transport (although the data here is limited—other areas of emissions production are more difficult to measure). On a broader level, despite its potential for carbon reduction, the audiovisual sector has long been criticized for a series of environmentally-unsustainable practices [14], from carbon-heavy location shooting to an embrace of built-in obsolescence in media and digital devices. New media technologies are rarely more energy-efficient than the devices they replace [15]. They are usually made with toxic (hard to recycle) minerals, creating global mountains of e-waste, while the sector's digital revolution is underpinned by vast banks of power-hungry data centres [16].

A series of measures are clearly needed to address the sector's negative environmental impact, ranging from reducing energy consumption and optimizing resources to encouraging green investment [17]. Innovation must play a key role here in shifting the industry away from business-as-usual [18]. In this article we discuss *green innovation*—now acknowledged as an increasingly important aspect of economics, accounting and strategic management as a specific type of innovation which aims to minimize environmental damage and degradation [19]. Shu et al. [20] show how green innovation can improve the quality of utilization or resources, enhance the level of productivity, and increase the affordability of media production. Green innovation can also have a positive impact on business creativity and green identity [21]. There is, however, only limited research around the levels of adoption of green innovation inside the audiovisual sector [22], where the concept remains ill-defined and poorly-captured by reliable data [23].

To bridge this gap, our article aims to better understand the extent and nature of green innovation in the audiovisual sector. In doing so, the study combines quantitative measurements—levels of adoption of green innovation in Wales—with case study analysis of identified green innovation best practices in Wales. The article is structured as follows. In the first part we draw on the emerging literature and initiatives around green innovation in the audiovisual sector, both at EU and UK/Wales level, that underline the efforts to deal with the complexity and limited understanding of green innovation. We then present our mixed method approach, aimed at a better assessment of forms and adoption levels of green innovation. In the next section, we present findings and draw upon this evidence to propose an extended framework for approaching green innovation in the audiovisual sector, which contributes to a more comprehensive analysis of green practices. In the final section, we highlight the positive impact of holistic approaches/frameworks on mapping green innovation in the audiovisual sector and make some recommendations for the future.

2. Materials and Methods

2.1. Research Context

Following the United Nations' Sustainable Development Goals and other calls for action to tackle climate change and preserve oceans and forests, private and public entities have developed an array of strategies, policies and initiatives to help audiovisual businesses reduce their environmental impact [24]. A set of measures has been put in place both at pan-European and local levels to encourage sustainability compliance in the audiovisual sector [25]. These include impact measurement tools/toolkits, training, and Research & Development funding [26]. Both top-down (green policies, strategies and initiatives) and bottom-up (green trends and initiatives) measures point to the efforts of the sector to gear towards green innovation.

2.1.1. Top-Down Measures for a Greener Audiovisual Sector

At a pan-European level, a series of policies, strategies and initiatives are in place to support the industry to reduce its environmental footprint and invest in green innovation. The European Commission's Green Deal [27], for example, is one of the most important pan-European policy instruments for tackling environmental compliance. It includes dedicated measures on the circular economy and enforces/expands existing regulation. It aims to set specific guidelines for industry actors to comply with more environmentally friendly measures. Many of these measures are relevant for the audiovisual sector (e.g., the EcoDesign Directive, the New Directive on Single-Use Plastic Products, etc.).

From a strategic perspective, European Union (EU) funding programmes (2014–2019) have encouraged investment in innovation as a way of making the sector more sustainable. Solutions such as hydrogen-powered gensets, automated scripts and Virtual Machines, machine-learning dispatchers and high-performance computing data centres, hybrid content delivery networks and solutions for storing electrical energy (e.g., Zero Emissions Generator) that have been developed by funded projects, testify to existing green innovation practices [28] along the entire value chain. The Creative Europe MEDIA programme (2022–2026) aims to continue this legacy of investment in green innovation practices through four specific funding strands which foster the greening of the industry and encourage inclusion, equality, diversity and participation.

Lastly, from the perspective of pan-European initiatives, we can mention two important networks which aim to support green transition through a variety of tools, services and actions created for audiovisual businesses: Green Regio and the European Film Commissions Network. Green Regio [29]—a sub-group of the Cine Regio network, comprising 43 regional film funds across Europe—aims to support audiovisual actors in their green transition. It represents a good example of collective efforts to raise awareness and share knowledge on sustainable film production practices, measures and policies. Its activity has fostered the emergence of a series of pan-European tools such as Green Film, Eureca and the ECOPROD Charter, which offer certification systems for film productions, carbon calculators, and access to green providers. The European Film Commissions Network [30] (EUFCN) is a non-profit association with a similar mission, sharing green protocols, tools and best practices developed within the network. The European Film Agency Directors association (EFAD), through its Sustainability working group, exchanges best practices and information on sustainable initiatives launched by national film funds and other partners. At a national level, agencies such as the Det Danske Filminstitut [31] (Danish Film Institute, DFI), Screen Ireland [32] (Fís Éireann), and Vlaams Audiovisueel Fonds [33] (Flanders Audiovisual Fund) have developed specific strategies and plans to encourage the industry to adopt more sustainable production levels. For example, Screen Ireland has recently launched its four-year strategy to increase the green footprint of the sector.

While the EU is moving towards a more cohesive and collaborative approach for greening the screen sector, the UK is putting responsibility and ambition at the heart of green policymaking. Within the UK, the Climate Change Act [34], as well as several policies on waste and recycling, require businesses to meet minimum standards to reduce their impact on the environment. It is fair to say, however, that there is a gap between these regulations and ambitious (but necessary) targets for moving towards net zero. Thus, for example, compliance varies across the size and type of businesses. Although public bodies have to use procurement activities that meet certain green standards (ISO 14001/registration under EMAS), private entities—who compose the majority of the audiovisual sector—do not fall under these rules.

A variety of other non- (or quasi-) governmental organisations in the UK have put measures in place to support a green transition of the audiovisual industry. The British Film Institute (BFI) requires any major production that receives BFI funding to provide mandatory carbon reporting and participation in carbon literacy training. The British Academy of Film and Television Arts (BAFTA) requires broadcasters and production companies to decide what level of compliance they want to adhere to—either Footprinting

(e.g., UKTV, Channel 4, Netflix UK and Channel 5) or full Certification (BBC, Sky, ITV). Albert, an environmental organisation aiming to encourage the TV and film production industry to reduce waste and its carbon footprint, has created the Albert calculator, a tool which is slowly becoming the standard for TV programme makers in the UK (Albert-compliant TV programmes are credited on screen). Digital Catapult, the UK authority on advanced digital technology, has entered a partnership with the UK Government to develop programmes for the UK's digital technology ecosystem. The collaboration resulted in the setup of the UK's first R&I studio for virtual production [35] aimed, at least in part, at reducing CO_2 emissions by minimizing the need for location shooting. The recognition that more needs to be done in this area has also led to the signature of the Climate Content Pledge [36] by some of the UK's major TV channels (BBC, ITV, Channel 4 and Sky). The pledge is a formal commitment to increasing the amount of and improving the quality of climate change storytelling. While the above-mentioned measures and initiatives show attempts to address the challenge of climate change that exceed formal regulatory requirements, they have yet to create the profound culture shift that meets the scale of the climate crisis.

On a regional level, the Welsh Government has recognized the need to drive the sustainability of the sector by enforcing green policies and commissioning tools (carbon reporting methodology) that can support public and private organisations to align with environmental legislation. To this end, it has put the Net Zero challenge at the heart of a new Welsh Government Innovation Strategy [37], while the Well-Being of Future Generations Act is a ground-breaking initiative that obliges all Welsh Government policies and practices to consider the impact on future generations—an obligation in which the need to address the climate emergency looms large. Film Cymru [38] is the main Welsh industry body supporting the greening of the audiovisual sector. It adopts a four-level approach that combines research (studies), innovation and collaboration (Screen New Deal, Greening the Screen), funding (Green Cymru Challenge) and training (building 'green' skills). Its future strategy focuses on strengthening green/skills funding and aligning to European initiatives (European Audiovisual Observatory).

2.1.2. Bottom-Up Measures for a Greener Audiovisual Sector

Despite being known for its powerful collective imagination, the audiovisual industry has, to date, struggled to rethink environmental sustainability [39]. This is partly because the audiovisual industry has a traditionally hierarchical structure with project-based and fluid workflows [40], which makes it slow in adopting systemic change [41]. It works to tight pre-production timeframes, with frequently-changing production teams and spontaneous decision-making processes [42]. Moreover, film and TV production companies are highly dependent on other polluting industries such as fashion, energy, transport, and media technology [43]. The sector's relationship with its supply chain therefore has to be built-in to greening initiatives.

Despite these structural and industrial challenges, there is industry consensus about the need for more sustainable practices and approaches in managing productions [44], leading to a series of new roles and initiatives. Green shooting [45], for example, involves establishing greener practices at pre-production, production, post-production and promotional stages. These practices can be both tangible (such as the use of sustainable solutions such as eco-vehicles, recycling bins, avoiding paper scripts, opting for vegan makeup and means on the set) and intangible (such as the team's concern for the environment and responsible behaviour on the set). This has led to the new role of the eco-manager/eco-supervisor/green production manager [46]. There is, however, a lack of understanding about the responsibilities of the eco-manager, their decision-making capacity, and how this role should work transversally within the company [47].

On the educational side, interest in driving change towards green practices has been manifested through initiatives such as the piloting of green micro-credentials as part of the latest push of universities to foster new skills [48]. Lusofona University has recently piloted

the first micro-credential course for green consultants in the audiovisual sector [49]. The course aims to form a new set of professionals, with skills geared towards the management of sustainable systems and processes. While these developments highlight an industry that is gradually moving towards sustainable production, it also highlights the numerous challenges [50] and the need for a more cohesive and coordinated approach to green sustainability that works across practice, education and politics [51].

The pan-European and UK context illustrate that policy measures and strategies work on disparate levels, with the notable absence of harmonised institutional and social frameworks. As a result, the adoption of green practices is more often a matter of personal conviction rather than a broader collective responsibility [52]. According to Sorensen et al. [53], the audiovisual sector is hampered by a series of structural, industrial and policy challenges. For example, isolating green policies from other audiovisual policies (e.g., training, employment, co-production) has led to a fragmented understanding of the concept of environmental sustainability. This adds to the lack of shared reporting and auditing systems, which has rendered the monitoring of environmental compliance difficult to implement. The willingness of the industry to respond to environmental challenges is thus hampered by both the structural practices of the sector (such as timescale pressures on content production and a commissioning process where environmental concerns play, at best, a secondary role in decision-making) and the deeply ingrained mindsets and habits that are difficult to change, as well as by the lack of clear mandates from public organisations. Moreover, while cost reduction is a key driver for green innovation [54], the general perception of green innovation is that in the short-term, they increase rather than decrease costs (by requiring, for example, time and resources to meet higher levels of compliance, or researching green suppliers) [55].

To overcome some of the structural and industrial challenges faced by the industry, green innovation needs to become the rule rather than the exception. This is currently not happening, as shown above. For example, identified innovations funded by EU projects can still be considered marginal solutions, due to low levels of adoption by the industry. Moreover, the lack of understanding of innovation processes and practices contributes to a failure to see their long-term benefits. To close the gap between policies, strategies and the adoption of green innovation by the industry, we first need to better understand how much and in which ways these companies create green innovation. The next section discusses the methodological approach of this study that is designed to address the identified gap.

2.2. Methodology

Green innovation has become a key tool for sustainable development [56]. One of the most well-deployed approaches comes from the fields of management and strategy [57], with a prevalence of studies covering the automotive, semiconductor, electronics and electricals, IT and pharmaceutic sectors. A broad diversity of theories and frameworks try to contextualise research around green innovation practices, meaning that the literature is fragmented and poorly-integrated in terms of conceptual frameworks [58]. Systematic review studies [59] highlight the need for developing mixed or even experimental methods able to progress our understanding of green innovation. These studies underline the fragmented nature of the research field, indicating that there is no agreed or overarching definition of green innovation [60]. While most definitions share the idea that green innovation encompasses products, services or processes with a reduced environmental impact, they adopt different approaches to its location and purview. Some focus on the application of innovation in technologies [61], some look at the aim of achieving sustainable development and the conservation of natural resources [62], and some focus on the adoption of environmentally-friendly raw materials during the manufacturing or design process [63].

Overall, we see a preponderance of technology-driven approaches, evidenced by studies differentiating between the capacity of high-tech industries and low-tech industries for engaging in innovation [63]. This is complicated by the broad terminology surrounding this type of innovation—green, ecological and environmental—that Schiederig et al. [64]

acknowledge as being used interchangeably and thus contributing to a lack of a unified vision [65]. Perhaps because much of its content is seen as ephemeral rather than material (and despite its dependence on carbon-hungry technologies), there is little research addressing green innovation practices in the creative industries, whose considerable carbon footprint is often overlooked [66].

To bridge this gap, we define green innovation as the adoption of production, services, and technologies that minimize environmental risks. In so doing, we expand on the technology-oriented definition of green innovation used by Kemp and Pearson [67] to make it more inclusive of the variety of innovation typologies—be they process-, product- or system-related. Building on this definition, we propose a mixed method approach that aims to measure the extent to which firms implement green practices and how these levels are shaped by different forms of research and development (R&D), leading to innovation. R&D is more broadly understood as the 'creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of economic, cultural or social value of available knowledge' [68]. To measure adoption levels for green innovation, we first conducted a survey with Welsh creative businesses. Drawing on the findings of the quantitative analysis, which mainly indicated the problematic adoption of green innovation despite a fairly strong business value associated with such practices, we decided to conduct more in-depth analysis through case studies. To this end, we identified nine examples of green innovation in the Welsh screen sector and analysed their innovation process. This enabled us to better understand how the dynamics governing such practices condition adoption levels. The qualitative analysis also highlighted the way in which innovation approaches could be better organised based on specific criteria. This has ultimately led us to formulate a new framework for mapping green innovation in the audiovisual sector, the benefits of which we discuss in the closing section of this article.

3. Results and Discussion

In this section we present the design of our quantitative analysis, discuss its findings and establish how these shaped the next stage of the study. We then provide the results of our mixed method approach and how they informed the development of a framework that enables a more organised mapping of green practices in the audiovisual sector. For our analysis we focused on the audiovisual sector in Wales/Cardiff Capital region, which represents an important part of the creative economy, with a Gross Value Added estimated at £211 m for 2021 [69] and which contributes with around 3000 tonnes of greenhouse emissions [70] to environmental impact.

3.1. Quantitative Analysis: Measuring the Adoption of Green Innovation in the Welsh Audiovisual and Media Sector

Between March 2019 to December 2021, we surveyed 388 Welsh creative businesses (including companies and sole traders), asking them how they were innovating. The definition of sub-sectors was informed by the statistical classification of economic activities in the European Community (NACE codes). Overall, creative businesses were falling within four main sub-sectors:

- film, tv, radio and photography
- Music, performing and visual arts
- IT, software and computer services
- Publishing

We identified the 112 respondents falling within the NACE codes for film, TV, radio and photography (audiovisual sector), making up almost 30% of total surveyed businesses. We then compared the responses of this sub-sector with other 3 sub-sectors, to assess the differences in adoption levels for green innovation,

The survey was designed to assess three major categories of impacts for innovation: environmental, cultural and societal. This decision was driven by the acknowledgement

that innovation can have different outcomes and impacts [71]. Each of the three types of innovation impacts was measured using the likert scale system indicating if these were always, often, sometimes, rarely or never a result of the innovation process. This means that each business had to assess how often or rarely their innovations had an environmental, cultural or societal impact. A fourth variable was introduced in the survey to measure the business value of innovations. By asking respondents to say how often or not their innovations create business value, we looked at how quickly research and development processes lead to commercial outputs rather than to non-commercial ones. This is an important indicator of the business efficiency/performance for innovations [72] and thus proved fundamental for measuring adoption levels for green innovation.

Results show that only 17% of audiovisual businesses are frequent green innovators. This is on average 10% lower than for other sub-sectors where green impact is more frequent. However, an important share of audiovisual businesses are moderate green innovators, a similar situation to the music, performing and visual arts sub-sector, but unlike the publishing and IT domains where there are fewer moderate innovators and more frequent innovators. Figure 1 provides an overview of respondent groups based on the frequency with which their innovations have a green impact.

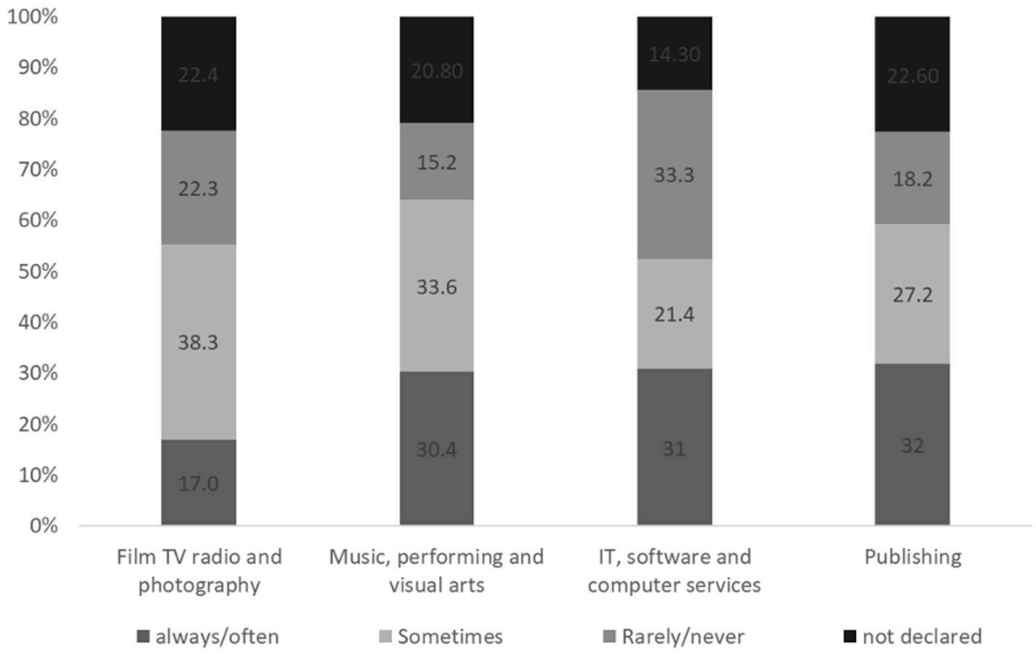

Figure 1. % of creative businesses creating innovation with an environmental impact by sub-sector.

Measurements of the fourth variable of the survey unveiled also that the audiovisual sector is less likely to attach business value to green innovation compared to other creative domains. For example, only 21% of audiovisual companies attribute a high business value to green innovation, compared to other sub-sectors, such as publishing, where 43% of respondents perceive a high business value for green innovation (see Figure 2 below). By contrast, we found *no* respondents in the IT, software and computer service sector who attributed a low value to green innovation. This may partly reflect the findings of studies showing tech-intensive industries as more prone to undertake green innovation. Nevertheless, more businesses attribute a high value to green innovation than businesses which often create green impact. This indicates that the business potential of green innovations remains fairly strong for the audiovisual sector even if such innovations are not adopted on a large scale.

As revealed by the survey, the low presence of high-frequency green innovators in the audiovisual sector points to a reluctance—or unawareness— of Research & Development as a viable path to greening their sector [73]. Research & development remains in fact a

potential route to green innovation, but not the only one [74]. Some businesses conduct research to improve business processes without necessarily resulting in commercial outputs. While this may reflect the nature of a sector which is often unfamiliar with R&D processes as a route to innovation (especially those that are not technology-based), the same could be said of other creative sectors, where enthusiasm for green innovation is higher. So, while most of the audiovisual companies in the Welsh sector are small, with limited access to R&D budgets, this is typical of the creative industries overall.

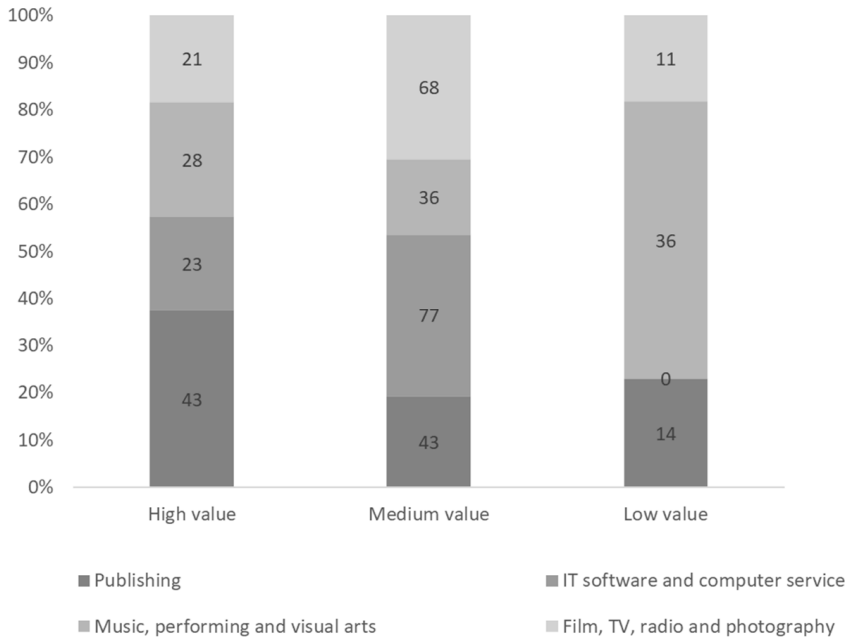

Figure 2. Perceived business value of high-frequency environmental innovations by sub-sector.

The uncertainty, novelty and systematic criteria defining the R&D processes [75] represents an important factor hampering green innovation. As a result, businesses can easily associate new (green) technology development with higher costs/investment and uncertainty, compared to its productivity generated throughout its lifetime (actual added value). However, our survey suggests that this is a particular challenge for the audiovisual sector. To better understand the barriers and enablers to innovation for the sector we decided to conduct a qualitative analysis of green innovations and their specific R&D routes.

3.2. Qualitative Analysis: Case Studies Approach of R&D as a Viable Route to Green Innovation

In our qualitative study we identified 9 case studies of green innovation in the Welsh audiovisual sector, all part of the R&D initiative titled Clwstwr [76] which focused on audiovisual innovation in the Welsh media sector. Clwstwr was part of an ambitious AHRC funded scheme (the Creative Industries Clusters Programme), in which, for the first time, the creative industries were given substantial R&D investment from the UK industrial strategy. The CICP created 9 creative industries innovation clusters across the UK. Our sample was drawn from 120 Innovation projects with creative industry partners funded by Clwstwr between 2019 and 2022 and was representative for green innovation. We analysed the specificities of the 9 R&D routes based on the type of innovation they were proposing and the associated green impact (assessed against criteria of the Screen New Deal).

The mapping revealed three main pathways through which R&D routes lead to green innovation: solution-oriented route (R&D aiming to support the development of concrete commercial outputs), content-oriented (R&D focusing on audiovisual content as a medium of innovation) and mindset-oriented (R&D that is oriented towards achieving an overall change in the industry towards more sustainable processes). While the first two routes are commonly found in studies on green innovation research, the third route is less present in

current literature [77]. This route represents a holistic mode of researching and developing innovation that is in line with green principles and follows an ecosystem approach [78]. In the following section we discuss the specificities of each route to innovation, focusing on the associated opportunities and challenges which come to support and strengthen our quantitative fundings.

3.2.1. Solution-Oriented Route

The first most common path to innovation works towards the development of specific solutions. In the audiovisual sector, such solutions can be products, services and technologies that reduce environmental impact across different stages of the audiovisual process (pre-production, production and post-production). three out of our nine identified green innovations have chosen this path to create specific solution such as a cloud-based digital product, a plugin to visualise production sets and a remote editing toolkit:

- Pre-production: A cloud-based digital product that provides production design and drawing management to the film and television Art Department. The solution contributes mainly to reducing impact in two areas defined by the Screen New Deal: production materials (paperless and remote working practices reduce the generation of waste) and production planning (shared tools for collaboration that maximize the focus of the procurement process and streamlines production processes).
- Production: A plugin to visualise virtually created sets, scenes and worlds by using VR to provide a realistic sense of scale/detail. The solution provides new ways of working by enabling users in remote locations to work on and share project files in a 3D space, which reduces impact across two areas defined by the Screen New Deal: production materials (waste connected to physical sets) and production planning (collaboration tools for the delivery of productions and virtual planning that minimize resource use)
- Post-production: A remote editing toolkit that enables teams operating from different locations to work on the same material without the need of physical travel. In doing so, the solution contributes mainly to reducing impact across one area defined by the Screen New Deal: studio and location (reduces transport/travel demand and associated emissions).

These examples follow an innovation roadmap with clear and measurable outcomes that are addressing challenges associated with the unsustainable consumption levels of the sector. As shown above, all three solutions aim to reduce the environmental impact in different areas defined by the Screen New Deal. In this case, the R&D strategies leading to innovation are designed around the identification of a specific challenge that needs to be solved through a concrete solution. While this represents a commercial return for innovators in the long-term, in the short term this route requires time and resources to invest in user testing and refinement of the solution, which can easily become difficult to sustain especially for small innovators.

3.2.2. Content-Oriented Route

Content creation and storytelling are some of the most powerful strategies for engaging audiences in meaningful ways on a variety of topics. The second identified path works with content creation as a powerful medium for raising awareness about climate change and contributing to a more sustainable media industry. In this category we identified three examples of animated content, each targeting climate emergency through different narrative strategies:

- Engaging storytelling: The Promise is an animated film about how one person can make the world greener and fairer. It is based on The New York Times Best Illustrated Book of the same name, written by Nicola Davies and illustrated by Laura Carlin. Set as an urban fairy tale, The Promise uses engaging storytelling strategies to engage audiences with positive environmental actions.
- Audiovisual techniques: Following the migration of white storks as they navigate man-made perils, this film invites viewers to fly with storks as they migrate from

Germany to Sudan, navigating perils including pollution and pesticides. In addition to its narrative structure, the animation uses a distinctive 'zoom' feature to draw viewers along the stork's journey. The animation was informed by research papers, GPS maps, photographs and interviews from the Max Planck Institute of Animal Behavior, offering a solid research foundation for the story.

- Educational approaches: Obki is an animated series featuring the original character Obki, a loveable alien, on his journey to be a positive force for good on Earth. Using an educational lens, it explores issues around climate change in an informative and entertaining way for 5–9-year-old children through Obki's adventures with his friend, the Orb.

As exemplified through the three case studies, this route to innovation aims to create dedicated audiovisual material and new formats (e.g., the eco-thriller) that raise awareness and educate towards action on climate change and environmental protection. R&D strategies designed around new content creation can take technical avenues (working with audiovisual techniques and effects) or more 'soft' approaches, including storytelling and educational methods. While this route to innovation can sometimes have a quicker return for innovators than the development of green solutions, which is more long-winded, it does require the mobilisation of highly creative capacity and skilled teams able to transform the creative vision into tangible results. Shared IP resulting from these innovations can also pose challenges for innovators.

3.2.3. Mindset-Oriented Route

In our analysis, we identified a third route to innovation that is less straightforward in terms of outcomes compared to the first two ones. Instead of focusing on addressing a specific problem, these innovations deploy a more complex approach to solving the environmental challenges of the audiovisual sector. Initiatives following this route adopt a green mindset approach aimed at triggering systemic change towards more environmentally sustainable practices. They adopt specific actions with more wide-reaching impacts, that generate an ecosystem of sustainability rather than providing targeted solutions. We have identified three projects falling within this category:

- A new service for greening animation: a route map to reaching net zero through the development of a new economically sustainable service. Dedicated to the animation, games and post-production industry, the route map was prototyped using in-depth interviews, carbon footprint analysis, co-creation workshops and public/private consultation surveys. It provides a new collaboration model to reach net zero by 2030. Although seeking tangible solutions in different areas of sustainability—energy and water, studio buildings and facilities, and production planning—the route map goes from the creation of a single solution to offering a new economically-sustainable service.
- A sustainable alternative for location filmmaking: a new method combining low-cost tools and techniques for film production to replace location filmmaking with a sustainable alternative. Aimed at creating a new film production system, this project combines different approaches: discussions with subcontractors/motion graphics experts, production/post-production tests, and business model development. Although it experiments with different existing technologies, the system takes a novel approach to making production greener, involving a wholesale re-imagining of how we tell stories on screen.
- A green infrastructure model for productions: a sustainable and collaborative infrastructure model to support the future of film and TV production. The model combines carbon footprint analysis with reporting on sustainability success stories and concept development for new apps/platforms. In doing so, it provides a production model that leverages new learning and systems to move towards a greener sector.

Although this route to innovation can include the creation of products, services and technologies, these often have a broad impact and tackle large-scale problems. R&D roadmaps for reaching these solutions are very complex, as they often involve mixed

methodologies drawing from multiple research domains. Therefore, innovations following this route are more adapted to foster models, systems and strategies rather than tangible products. Such innovations pose an important challenge to businesses in terms of complexity and uncertainty of their underpinning R&D strategies. Moreover, the long-term impacts of these innovations remain at a rather abstract level and alternative business models are required to make them commercially viable. Although these innovations are not necessarily cutting-edge/disruptive, the considerable resources invested, and the time and planning that they require, often render them inaccessible to businesses.

3.3. Towards a New Framework for Mapping Green Innovation in the Audiovisual Sector

Our survey revealed that Welsh audiovisual businesses are less likely to develop green innovations compared to other creative sub-sectors. In doing so, it suggested that the roadmap to innovation—most commonly taking the form of R&D processes—is cumbersome for the audiovisual sector. This was confirmed by our qualitative case study analysis where we identified three roadmaps to green innovation, each connected to a specific set of challenges. This shows that while the uncertainty, novelty and systematic criteria defining R&D remain important factors hampering innovation, the situation is much more complex than that. This is due to the specificity of each type of R&D, which affects the nature of green innovation. As a result, being able to identify the specific route to innovation in the audiovisual sector is important, insofar as it sets out expectations for innovators and provides them with a context for their innovation process. Moreover, offering a systematic approach for framing innovation practices based on R&D processes contributes to rendering research around green innovation less fragmented than it currently is. Therefore, a framework for mapping green innovation practices for the audiovisual sector based on different R&D routes, can have both practical and theoretical benefits.

The framework that we propose is based on the three routes to innovation that we identified in our qualitative study: the solution-oriented route, the content-oriented route, and the mindset-oriented route. Each route provides a specific roadmap to innovation, meaning it implies determined R&D practices, foresees typical forms of innovation outcomes, and is characterised by a series of particular challenges. As outlined by our case study analysis, the solution-driven route is more straightforward in terms of final outcome (technology, product or a service). R&D routes aiming to develop such solutions often try to solve a clear-cut green challenge (e.g., reduce energy consumption, waste production or other damaging impacts on the environment). Nevertheless, they require solid investment and time for development and are thus not very accessible for small businesses. Examples for the first route include, among other things, solar energy-driven power sets (LED/ solar generator supplies) and biofuel-based technologies. The content-driven route looks at content creation as the main driver of innovation. Examples include animations, immersive experiences, and installations, but also new genres such as the eco-thriller and trans-media approaches to content creation (e.g., for augmented, virtual and mixed reality). Because R&D strategies designed around new content creation can take different avenues (e.g., more technical vs. soft/design approaches), outputs are less tangible than solution-driven innovations and much more reliant on IP protection. Especially when mobilizing complex and multi-author creation processes, content-based innovations are difficult to protect and manage. Nevertheless, such roads to innovation represent powerful tools insofar as they draw upon the vast pool of creativity distinguishing the audiovisual sector in order to activate collective imaginaries towards greener mindsets. The third and last route to innovation deals with a more systemic approach to tackling green challenges. Although innovations following this route can take the form of concrete solutions, they are better expressed as systems, models and strategies that contribute to a systemic shift inside the industry. This is mainly due to the challenges that these R&D routes are addressing, which are much broader than the clear-cut energy or waste problems tackled by solution-driven innovations. Although such routes to innovation can provide important transformative and holistic shifts towards a greener mindset of the audiovisual sector, they are often very

complex to set up and require extended timelines. R&D routes to innovation which adopt this ecosystem approach often integrate social and cultural elements to trigger change. As a result, these forms of innovation can sometimes be hard to separate from cultural or social innovations. Due to these complex processes and challenges, R&D routes to green innovation are many times inaccessible to small businesses, as they need to be supported by solid investments (time and resources), as well as by highly skilled and transdisciplinary teams. Examples of innovations that follow mindset-oriented routes include, among other things, collaborative models across the production value chain, new film production systems, and sustainable infrastructure. Figure 3 below provides a synthetic overview of the proposed framework.

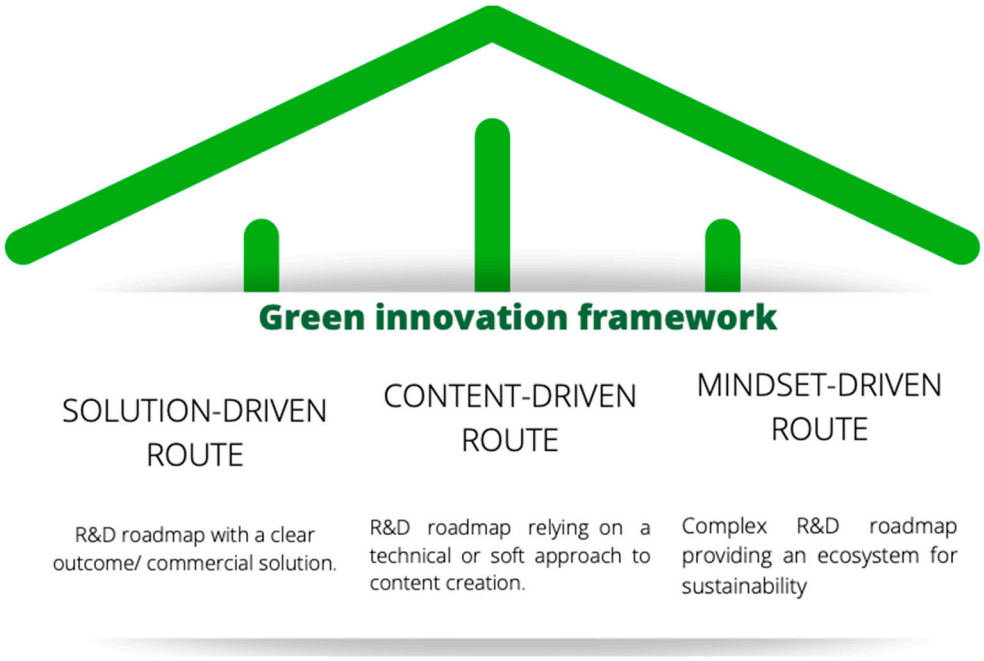

Figure 3. Framework for understanding R&D roadmaps to green innovation in the audiovisual sector.

From a practical perspective, the proposed framework can prove to be a useful guide, especially for businesses who are new to the field of R&D&I. As previously detailed, by providing a description of each route to innovation, businesses gain more clarity on the overall process and can more easily plan their innovation projects. The small size of most audiovisual companies (and, indeed, creative industry companies in general) means that most do not have the resources to commit to investment in R&D, so they need to attract external funds [79]. Using this framework, businesses can identify early on the type of R&D route they need to go down and search for adequate funding and support to develop their innovations successfully. The framework can thus support a better knowledge and diffusion of the required R&D approaches for green innovation. After all, the rethinking required to meet the challenge posed by the climate crisis—and the need to move quickly to net–zero—will not be achieved without the kind of creative and systematic work that is intrinsic to the R&D process.

From a theoretical perspective, the framework offers an expanded vision of green innovation through the inclusion of the mindset-oriented route, which places green innovation in a broader context that is not dominated by overly-technocratic definitions or content-specificity [80]. In doing so, it contributes to rendering the definition of green innovation more inclusive while foregrounding the essential role of R&D in fueling processes and driving change. This is even more important as R&D represents a newer area of study and its effects on innovation are still unclear [81]. The examples we describe in our case study analysis—all of which involved undertaking R&D to enable innovation—suggest that while R&D is helpful in the development of green solutions and green content, it is

essential to the systemic rethinking necessary for the mindset-oriented approach—a point we develop in our conclusion.

4. Conclusions

Moving quickly towards net zero in the audiovisual sector is a significant challenge. While we have seen the development of various initiatives to encourage greener audiovisual production, these are tentative and slow-moving—especially when matched to the scale and urgency of the climate crisis [82]. Unlike industries such as manufacturing or aviation, many of the environmental costs of audiovisual production are hidden [83], spread across different sites (generators on location, servers storing audiovisual data, individualised transport costs, food consumption, etc.). There are no obvious belching smokestacks or trails of fossil fuels marked across the sky. Indeed, while initiatives like Albert have made progress on data collection, the process of measuring the carbon footprint of film and TV production is neither easy nor straightforward [84]. Despite various initiatives, the lack of clarity around the carbon costs of audiovisual production allows those involved to see carbon emissions as somebody else's problem. This may explain the low proportion of those working in the audiovisual sector who identify the need to innovate to reduce their carbon footprint—a percentage that is low even for the creative industries in general.

The complexity of the climate challenge requires a sophisticated response, one that interrogates business-as-usual. Put simply, it requires innovation. This, in turn, requires the systemic creativity of the R&D processes. However, it also suggests that we incorporate a systemic level of enquiry, of the kind expressed by the projects described above adopting a mindset-oriented route to innovation. This involves thinking about environmental impacts at the very beginning of the creative process, creating stories that are easy to tell without, for example, location shoots requiring fossil fuel generators, significant private transport. or one-off sets, props and costumes. Greening the audiovisual sector thus becomes more of a systemic approach to change across all aspects of media production and its supply chains, developing comprehensive knowledge/skills and making green choices practical and cost-effective. Nevertheless, the conditions for pushing green innovation are linked to a predominantly project-driven and diverse sector, as well as to funding needed to support complex R&D processes. This means that R&D needs to become easier, offering the necessary time and resources to do R&D, especially for micro and small companies lacking the capacity to lead on organic innovation. Because the audiovisual sector is typically made up of disparate and small-scale businesses, this requires both coordinated industry action—by, for example, the main commissioners of audiovisual content through agencies such as Albert—and public investment (of initiatives like Clwstwr and the CICP programme) to enable small business innovation.

To this end, we recommend:

- A better alignment between policies/strategies and sector needs in order to provide the best support for green innovation.
- More investment in creative approaches to green innovation and skills development.
- The need for more tailored R&D funding programmes designed to cater for the needs of the sector.
- The creation of clear incentives and greater clarity about how investment in R&D by audiovisual companies can benefit them in the long-term.

The framework for mapping routes to green innovation, building on the findings of our mixed study, represents a step towards meeting the challenges posed by the limitations of overly technocratic definitions of R&D&I. It also shows that definitions need to align with the specificities of individual sectors instead of adopting a general approach for the entire creative industries. If we are to inform the research in R&D, we will need to:

- Conduct more consistent and holistic research into the nature of R&D practices in the audiovisual and media industry that enables the formulation of a unified sectoral definition for R&D.

- Undertake better mapping of the enablers and barriers for green innovation in the audiovisual sector.
- Explore the potential of the proposed framework to work in synergy with other tools to create a stronger link between forms of green innovation and the nature of R&D practices in the audiovisual sector.

The urgency of the climate crisis—and the distance the audiovisual sector needs to travel—means that this research cannot be a precursor to practical action but should take place alongside more of the practical and systemic interventions we propose. The proposed interventions, building on the findings of our mixed method form the strength and originality of our article. We acknowledge the geographical limitations of our study and the fact that applying the mixed method to other regions in Europe and beyond can provide not only snapshots of different green innovation contexts (including barriers and enablers), but also enrich and expand the proposed types of R&D routes for mapping green innovation in the audiovisual sector.

Author Contributions: The authors made the following contributions: R.L.—investigation and original draft preparation; M.K.—writing (review and editing); J.L.—writing and review; S.P. and G.M.—review. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Clwstwr, an ambitious five-year programme in the screen and media sector which was funded by the Arts & Humanities Research Council (UK) under the funding number AH/S002790.

Institutional Review Board Statement: Ethical review and approval were waived for this study, insofar as it did not involve the participation of any human subject.

Informed Consent Statement: Informed consent was obtained from all involved subjects involved in the study.

Data Availability Statement: The report for the original policy report on which this article draws can be accessed at: https://clwstwr.org.uk/green-innovation-screen-sector (accessed on 30 November 2022).

Acknowledgments: This paper and the research behind it would not have been possible without the exceptional support of the Clwstwr delivery team, who provided a deep insight into funded projects for the case studies.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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