MASTER'S THESIS- MASTER SUSTAINABLE BUSINESS AND INNOVATION

OVERCOMING BARRIERS AND REDUCING EMISSIONS IN THE DUTCH AUDIOVISUAL INDUSTRY

A case study with (PUPKIN)

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Abstract

Increased global awareness of climate change prompted various industries and private actors to adopt more sustainable practices. Similarly, the audio-visual industry began to embrace sustainability initiatives. However, in the Netherlands, such efforts are still in their early stages. Additionally, previous research highlighted how the common perception of a sustainable transition within production will require a higher financial investment when compared to unsustainable, traditional methods.

This study provided insight into sustainability within the Dutch audio-visual industry by addressing the following research question:

"What was the potential for CO2 emission reduction and related marginal costs for a (tentpole) AV production in The Netherlands?"

The project aimed to answer the question by compiling a comprehensive list of existing carbon mitigation measures which were organized according to five measure categories. The measure categories included transport of crew, on-set power, office power, accommodation and catering. The list was then narrowed down to seven carbon mitigation measures, which were ranked in order of cost-effectiveness by constructing a marginal abatement cost curve.

Results showed that switching to a hybrid solar or battery generator will result in cost-savings while also reducing emissions. This was the same for switching to a green electricity provider in the production office. The other five mitigation measures required additional financial spending but also showed considerable emission savings. This was especially the case for the mitigation measure where all electric vehicles were used on-set. Considerable emission savings were also seen in seeking accommodation that uses renewable sources of energy, as well as a switch to a vegetarian caterer and using a low-carbon fuel to power the on-set generator.

The stability of these results was checked by performing a sensitivity analysis which illustrated how results are multi-factor dependent, revealing that uncertain parameters can significantly influence the results. This highlights the necessity of conducting a meta-analysis that consolidates data from multiple productions

List of Acronyms

Acronym	**Definition**
GHG	Greenhouse Gas
COP	Conference of the Parties
AV	Audio-Visual
UN	United Nations
SPA	Sustainable Production Alliance
SME	Small to Medium Enterprises
VAF	Vlaams Audio-visual Fund
GPG	Green production guide
ATL	Above the line
BTL	Below the line
DoP	Director of photography
PD	Production designer
VOD	Video-On-Demand
HDCs	Hydroflourocarbons
N2O	Nitrous oxide
CO_2	Carbon dioxide
PFCs	Perfluorocarbons
SF6	Sulphur hexafluoride
NF3	Nitrogen trifluoride
DEFRA	Department for Environment, Food and Rural Affairs
EFs	Emission factors
MACC	Marginal Abatement Cost Curve
MM	Mitigation Measure
BAU	Business-as-Usual
NPV	Net Present Value
ES	Emission savings
OsP	On-set power
tCO_2eq	Tonnes of carbon dioxide equivalent
L	Litres
CIBSE	Chartered Institution of Building Service Engineers
kWh	Kilowatt hour
PA	Production assistant
EIB	European Investment Bannk
HVO100	100% hydrated vegetable oil
WTT	Well-to-tank
WTW	Well-to-wake
NEA	Netherlands Enterprise Agency
HVAC	Heating ventilation and air conditioning

1. Introduction

1.1 Global Climate Commitments and the Audio-Visual Industry's Response

The Paris Agreement (2015) assigned individual countries with responsibility for mitigating climate change and its harmful socio-environmental consequences (Falkner, 2016). As a result, each country was given specific targets for reducing their national greenhouse gas (GHG) emissions, with the goal of limiting global temperature increases to under 2 degrees above pre-industrial levels, while making additional efforts to achieve a 1.5-degree limit (United Nations (UN), 2021; Falkner, 2016). These goals were specified at the 26th Conference of the Parties (COP26) in Glasgow in 2021, including the target of a 45% reduction in global emissions by 2030 to achieve net zero emissions by 2050. These targets were set to encourage a collective, global response to the climate crisis.

The Paris Agreement has led to an increase in impact research on industries that contribute to climate change and further stressed pressure for these industries to meet national emissions reduction targets (Luo et al., 2023). The audio-visual (AV) industry, which includes the production, distribution, and screening of film and TV media (Oxford Economics, 2013), has received similar attention. Research by organizations dedicated to advancing sustainability in the film and television industry, such as the Sustainable Production Alliance (SPA) (2021) and Albert (2022), emphasizes the sector's substantial environmental impact. SPA's (2021) findings highlight the carbon footprint associated with tentpole productions, which are high-budget, high-profile projects crucial to supporting a film studio's financial performance, totaling 3370 tons (Afandi, 2023). While one episode from a tentpole TV series produces 77 tones of CO_2 per episode (SPA,2021). Similarly, Albert (2022) found that an average tentpole production in the UK generates 2840 tons of CO_2. This implies an interconnection between the financial dynamics of the industry and the consequent environmental impact. Tentpole projects are strategically produced to minimize financial risk within a company, ensuring a net profit for the studio (Afandi, 2023). This strategic positioning highlights the industry's reliance on tentpole films as economic anchors while also emphasizing the ecological implications of these blockbuster projects.

A 2006 UCLA study also found that film production in Hollywood is a larger contributor to GHG emissions than manufacturing, apparel, or hotel industries (Corbett & Turco, 2006). Other studies have also highlighted the importance of GHG emissions in the AV industry (Schwarzenegger et al., 2006; Calaveras, 2022), encouraging the recognition of a widespread problem by filmmakers. This was reiterated at the 2020 European Film Forum, whose main theme was sustainability (European Film Forum, 2020). The Forum acknowledged the importance of implementing best practices to reduce carbon emissions throughout the production process but noted the difficulty of standardizing best practices across the AV industry, as the dynamic composition of productions makes sustainable measures project-dependent (European Film Forum, 2020).

1.2 Knowledge Gap Analysis

The attention paid to the impact of the AV industry also led to the development of the Green Screen project funded by Interreg Europe (Interreg, 2020). The project partnered with eight European countries to improve policies and align environmental practices to introduce sustainable film and television production across Europe by reducing their respective carbon footprints (Interreg, 2020). It identified the following barriers to implementation: limited awareness of carbon-mitigating best practices in the production process, lack of government funding to implement sustainable film production for small and medium-sized enterprises (SMEs), environmental sustainability not playing a major concern in procurement, lack of reliable data on the impact of regional television and film production, and lack of a consistent tool to quantify and measure progress toward sustainability (Interreg, 2020).

Similar research was also performed in the context of the Netherlands by Keilbach & Spoler (2022) and Kohle (2022) who concluded that sustainable action within the industry is still in its infancy and recognized national barriers to a sustainable transition. Keilbach & Spoler (2022) detailed the main barriers include a lack of financial support, due to tight time constraints and strict budgets because of limited funding, as well as infrastructural discrepancies. Authors also noted that industry professionals are not fully aware of available carbon mitigation practices and the extent of their efficiency, which is supported by a lack of academic research that is specific to carbon-reduction in the Dutch AV industry (Keilbach & Spoler; SPA, 2021). In addition to this knowledge-gap, industry professionals also felt a communication-gap, where respondents felt unsure who should initiate the transition to green practices (Keilbach & Spoler, 2022). However, as of November 2023, the Film Funds have allocated responsibility onto the heads of Production wherein consultation with an Eco-consultant is required during pre-production (Dijksterhuis, 2023). Consultation will ensure that sustainability is tackled during the development phase of production and will require a pre-emptive carbon calculation as well as a carbon action plan to make the production eligible for additional funding by the Film Funds (Dijksterhuis, 2023).

Similar barriers were also considered by Callebaut (2022) and Mohebi (2022) under the Flemish AV fund (FAF) in Belgium. To address these concerns, authors implemented a marginal abatement cost curve (MACC) on a Flemish TV series, months after production and distribution. The tool was used to rank GHG MMs according to their cost-effective potential throughout a sustainably produced TV series following its release. The approach was the first and only to implement a MACC in the context of an AV production, leading to valuable insights which are although, limited to the scope of Belgium.

1.3 Objectives and Research Question

This research project recognizes the pressure enforced upon the Netherlands by the Paris Agreement to achieve the goal of a 45% reduction in GHG emissions by 2030. The project also accounts for the knowledge-gap barrier to implementation illustrated by Keilbach & Spoler (2022), as well as the Film Funds' new policy concerning mandatory carbon calculation and associated development of a carbon action plan (Dijksterhuis, 2023). Additionally, impact reduction research of the AV sector remains in its infancy on a global (SPA, 2021; Schwarzenegger et al., 2006; Calaveras, 2022) and national (Keilbach & Spoler, 2022; Kohle 2022) level. Therefore, this project's overarching goal is to add value to The Netherlands by providing insight into mitigating GHG emissions throughout the AV production process while also bridging the knowledge-gap by illustrating which MMs have the greatest GHG reduction potential. This will be done by implementing a MACC throughout the pre-production phase of a tentpole TV series, using the Dutch production company, Pupkin, as a case study.

With the application of the MACC, the objective of this paper will be to answer the main research question:

What is the potential for CO_2 *emission reduction and related marginal costs for a (tentpole) AV production in The Netherlands?*

This research project recognizes the previous application of a MACC in the context of an AV production, but it reiterates that Callebaut (2022) and Mohebi (2022) were the first and only to do so with a scope limited to Belgium. Moreover, their research was performed after release of the TV series – this project will be collecting data before release, throughout pre-production, the importance of this phase is elaborated on in chapter 2, section 2.1. Moreover, value will be added to their research as their results will be taken into consideration when choosing applicable MMs to the production.

2.Theoretical framework

2.1 Film making process.

To understand how filmmaking in the AV industry can adjust to limit carbon emissions, it is important to understand its phases (*Figure 1*). Strategic development, pre-production, production, post-production, and distribution are the typical five key stages of the production process. Depending on the project, each phase's intensity varies, but the cycle is the same for every project. (Honthaner, 2013)

The first phase, strategic development, encompasses the creative phase of the project where the planning and conceptualizing of the film/TV series is initiated and finalized. Logistical planning is then developed in the pre-production stage, this entails actions such as establishing the project's final budget, figuring out the project's scope, finding talent and locations as well as procuring the required equipment (Francis, 2022). The pre-production phase is considered vital when incorporating carbon-abatement measures into the project, since decisions regarding shooting-location, material, and talent sourcing could all contribute to increased emissions (Felder et al., 2008; Victory, 2015). Data collection of this project will be taken throughout the pre-production phase. The third phase includes the actual filming of the project where resource consumption is the most intensive (Felder et al., 2008; Victory, 2015). Post-production is the penultimate stage and involves video editing, incorporation of soundtrack and finalization of project for delivery for the final phase, distribution.

Figure 1: The AV production process

2.2 Outline of Departments

Responsibilities are divided into two categories on an AV production set; above the line (ATL) and below the line (BTL), as illustrated in Figure 2 (Backstage, 2022). ATL roles are responsible for the creative development and production of AV media, where professionals realize ideas form script to screen (Backstage, 2022). These professionals have a high impact on downstream emissions in the production process because major decisions about budget and location are decided within this category of professionals. BTL professionals occupy the logistic and technical roles of the production and do not provide input on the creative development of the project but carry out the vision curated by the ATL roles (Backstage, 2022).

Although there is a division between ATL and BTL, all departments work cooperatively to achieve their end-goal, this is illustrated by the grey arrows connecting all the departments. The direct relationships between ATL professionals and BTL departments are depicted by the black arrows. In Figure 2 The Director of Photography (DoP) is responsible for developing a film’s visual style by managing lighting and composition (90seconds, 2023). Logistic elements to capture the DoP’s vision are managed by the grip, electrical and camera departments, hence the black arrows between the DoP and respective departments. The DoP also works closely with the Production Designer (PD) who curates the set design to achieve the DoP’s vision for the shot. Therefore, the PD has a strong influence over the Art Department who must source the correct props and materials to create the set for the scene.

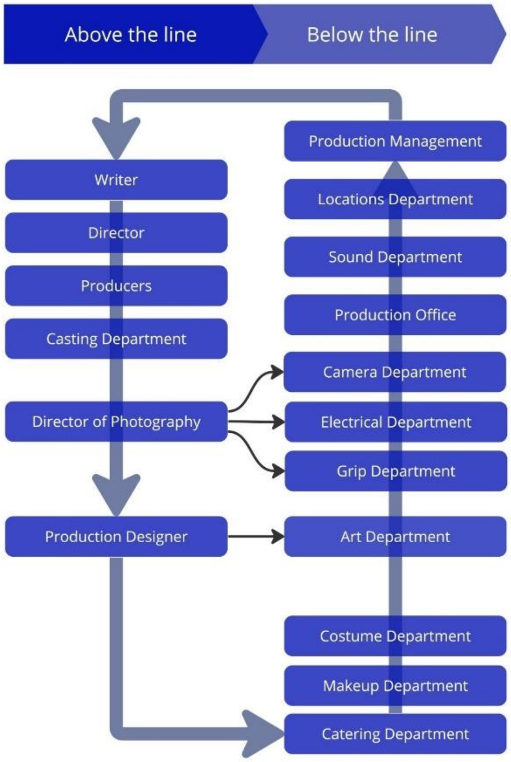

Figure 2: Outline of departments involved in an AV production based on desk research and feedback from industry professionals.

2.3 Impact areas

Departments, roles and their respective activities have varying contributions to scope 1, 2 and 3 emissions. Emission scope definitions in the context of an AV production are defined as follows:

Scope 1 direct emissions originate from activities which are owned or controlled by the production company (Albert, 2022: GHG Protocol, 2013). This refers to emissions from company-owned vehicles, boilers, as well as leaked refrigerant gases used for air-conditioning within company offices (Albert, 2022).

Scope 2 emissions are any emissions associated with the consumption of purchased electricity, steam, heat or cooling (Albert, 2022: GHG Protocol, 2013). They are consequential to the production company's energy use and are generated in facilities which are not owned or controlled by the company (Albert, 2022: GHG Protocol, 2013).

Scope 3 emissions are any indirect emissions that occur outside of any spaces that the production company does not own or control and fall outside of the definition of scope 2 emissions (Albert, 2022: GHG Protocol, 2013). This includes upstream and downstream emissions associated with purchased meals for catering, materials used on set, disposal and fuels the production company purchases (Albert, 2022).

Previous research separates contributing activities, irrespective of their emission scopes, between filming spaces and non-filming spaces (Albert, 2022). Filming spaces refer to any location where recording scenes takes place – this could be on rented location or in studios (Albert 2022). While, non-filming spaces refer to company offices, post-production studios and rented accommodation for cast and crew (Albert, 2022).

Emission intensive activities in filming spaces include using generators to power set and lighting and trailers for crew, makeup, catering and the electrical department (Film London, 2009). The emission intensity of generator use was described by Film London (2009), where the most intense emissions originated from generators to power the set and lighting, followed by those used to power cast trailers. Daily transport of materials and crew, air travel to overseas locations, catering options, set design and end-of-use treatment also contribute to emissions in filming spaces (Albert, 2022; Sustainable production alliance (SPA) 2021; Rüdenauer et al., 2022). Impact of vegetarian and meat-based catering options were explored in research by the VAF (Mohebi 2022; Callebaut, 2022). Authors found that a switch to vegetarian meals on-set and leaving meat-based as an option for request, compared to vice-versa, only caused minimum reductions in up-stream emissions since the base of the meal remained the same. Mohebi (2022) suggested researching a local catering provider to observe a potential greater decrease in emissions.

Unregulated waste generation from various departments is also significant to filming spaces (Pietari Kääpä & Marek Kaźmierczak, 2022). These include materials used in set design and construction such as wood, metal, plastics and paint, wardrobe and costuming by creating first-hand garments from textiles where scraps are discarded, and occasionally the final costumes when production ends (Keilbach & Spoler, 2022; Pietari Kääpä & Marek Kaźmierczak, 2022). Finally, catering and craft services also contribute to waste generation on media-sets (Keilbach & Spoler, 2022; Pietari Kääpä & Marek Kaźmierczak, 2022).

Non-filming spaces, such as production offices and rented accommodation for cast and crew, contribute to emissions through energy for heating, cooling and lighting (Albert, 2022; SPA 2021; Rüdenauer et al., 2022). The following impact areas were identified: Transport for crew and materials, heating and cooling within the production office as well as rented accommodation, fuel used for generator power on set and in studio, upstream emissions and downstream emissions of materials used on set as well as the meal base for on-set catering (see Figure 4) (Albert, 2022; SPA 2021; Rüdenauer et al., 2022, Mohebi 2022; Callebaut 2022). The contributing roles to the emission intensive activities are highlighted in Figure 3, the impact areas are further categorized into their scope of emissions based on the GHG protocol (2013), which are illustrated in the "Key" box in Figure 3 as well as Figure 4.

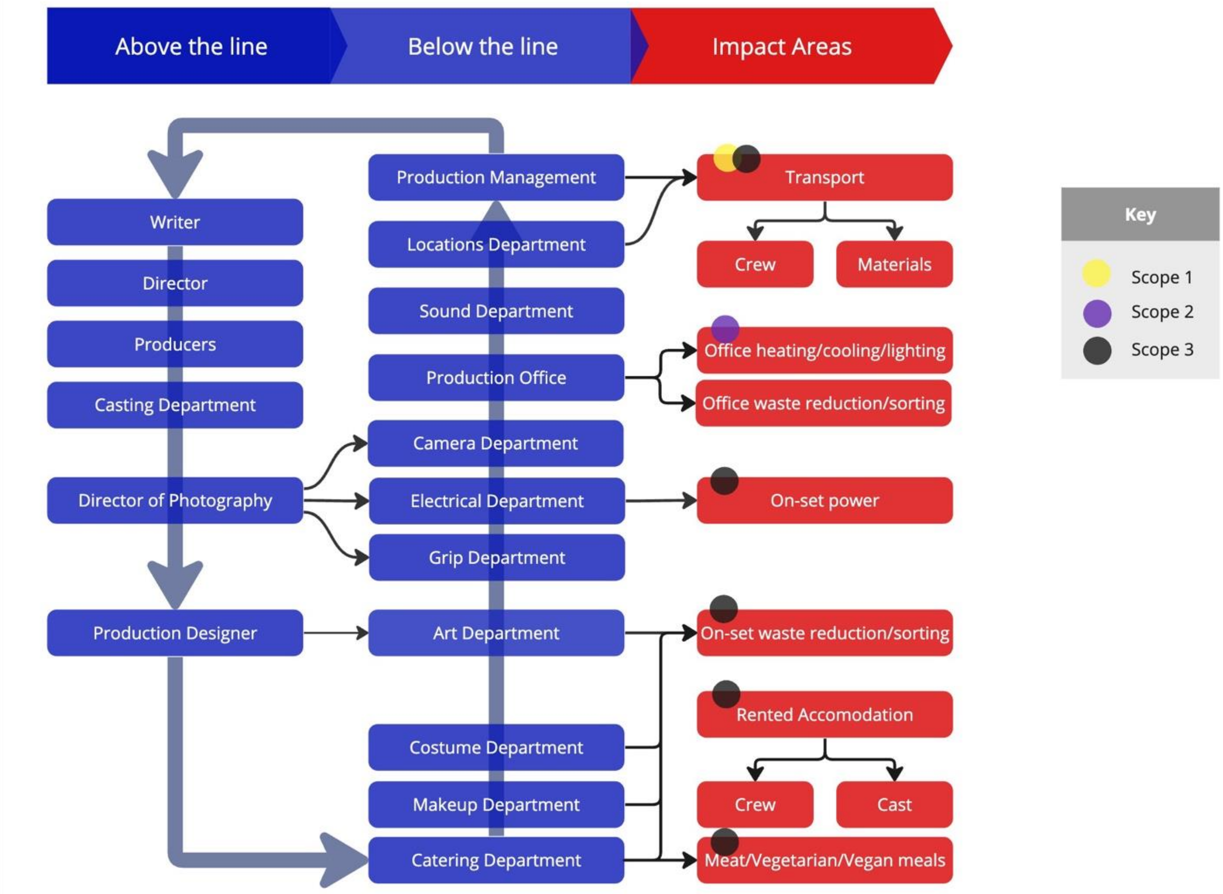

Figure 3: Outline of departments and respective impact areas which correlate to emissions (scope 1,2 and 3) .

The map outlined in this section (Figure 3) was used to approach the respective departments with the most impact during pre-production. This permitted a streamlined application of MMs and appropriate time and attention to be paid to activities that contributed to the most impact in terms of CO_2 emissions.

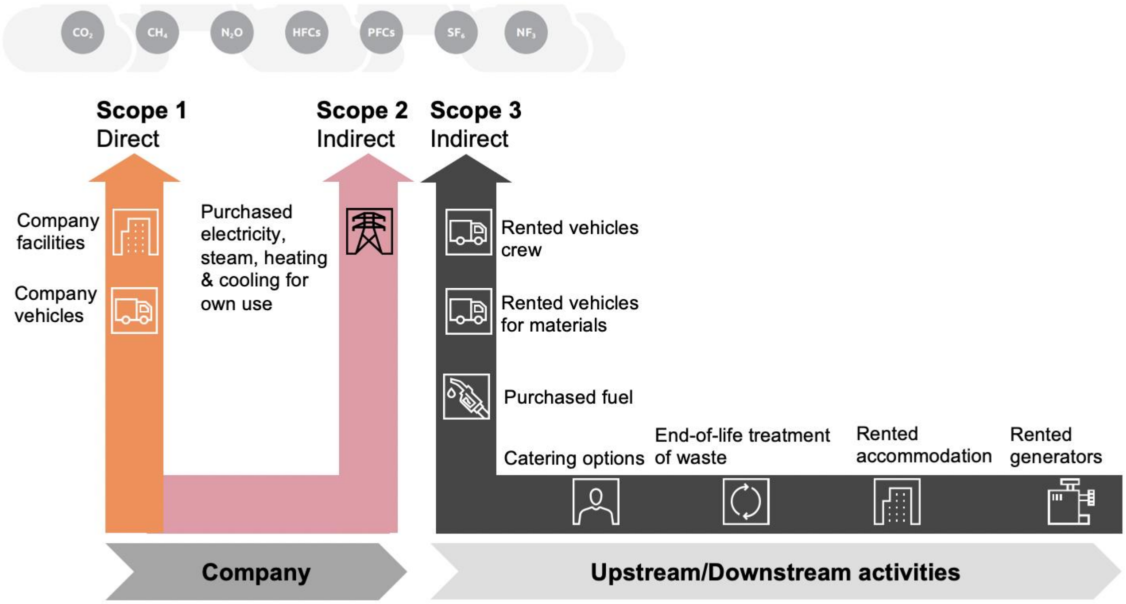

Figure 4: Impact areas and the scope of emissions they are responsible for.

2.4 The Albert Calculator

With the recognition of tackling the AV production industry's environmental impact came the introduction of new carbon calculator tools (Mohebi, 2022; Callebaut, 2022). These tools aim to assist production companies in measuring the efficiency of their chosen MMs, providing a valuable resource for informed decision-making in the pursuit of sustainability.

The Albert calculator is a tool in the AV production industry to measure the environmental impact of productions in terms of carbon emissions (Albert, 2022a). Developed by the UK-based organization, the British Academy of Film and Television Arts (BAFTA), Albert assists production companies in assessing and understanding the carbon footprint associated with their projects (Albert, 2022a). It considers various factors, such as energy usage both on set and in office, transportation and accommodation, resource consumption, waste generation and catering, providing a comprehensive analysis of the environmental impact throughout the production process (Albert, 2022a). This tool serves as a practical resource for the industry, facilitating informed decision-making and enabling efforts to reduce the industry's overall carbon footprint.

The calculator displays emissions in metric tonnes of carbon dioxide equivalent (t CO_2eq), encompassing the emissions linked to seven greenhouse gases (GHGs) specified by the Kyoto Protocol (Albert, 2022). These gases include carbon dioxide (CO_2), methane (CH4), nitrous oxide

(N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6), and nitrogen trifluoride (NF3), all of which contribute to climate change (Albert, 2022b). For projects based in the UK the calculator uses the Department for Environment, Food and Rural Affairs (DEFRA) emission factors (EFs) (Albert, 2022b). While for any projects overseas, the calculator uses the most reliable country specific EFs (Albert, 2022b).

The Albert calculator has been adopted as the official tool for projects seeking funding from the Filmfonds in the Netherlands (Dijksterhuis, 2023). Projects aspiring for external funding must utilize the Albert Calculator to track and report their environmental impact. (Dijksetrhuis, 2023). Productions can even go the extra mile to get certified through Albert's organisation. This certification involves the creation of a detailed carbon action plan, outlining specific measures to reduce emissions throughout the production process and measuring their impact (Albert, 2021). Albert provides a sophisticated online carbon-calculator, enabling measurement of the carbon footprint associated with production

2.5 MMs

Measuring environmental impacts throughout the production process is a practice that has only recently received attention, especially in the Netherlands. Therefore, addressing appropriate MMs, and understanding their efficiency is particularly difficult for production companies. This is because MMs vary depending on the type of production. So, each production needs a unique plan to minimize its impact, making it a complex task for production companies (Albert, 2022). Despite these challenges, recent studies suggest practical solutions for reducing environmental impact during production. These include using electric generators, opting for vegetarian catering, using electric vehicles, and switching to LED lighting (Albert, 2022; SPA, 2021; Rüdenauer et al., 2022; Mohebi, 2022; Callebaut, 2022). These efforts reflect the industry's strides in reducing CO_2 emissions, aligning with the global push for more sustainable film and television production.

2.6 The film-making process of Pupkin's tentpole production and its MMs

The television series produced by Pupkin, underwent a structured production period schedule divided into three shooting blocks, commencing in August 2023 and concluding in early December 2023. The initial block comprised a 20-day filming period, succeeded by a subsequent block lasting 21 days, and culminating in a final block spanning 17 days.

Throughout this period, Pupkin planned to implement notable MMs in the production. These included optimizing its transportation logistics through the adoption of efficient vehicles as best to their ability. Additionally, Pupkin has pursued sustainable practices in wardrobe management by sourcing second-hand clothing, intending to return items after production. The company also incorporated vegetarian meals into its catering plan throughout the shooting weeks, with one day per week dedicated to a meat-based meal. While these initiatives showcased Pupkin's commitment to environmental responsibility, it is acknowledged that certain impact areas identified in prior assessments remain unaddressed, mainly due to budget constraints.

Pupkin is also taking a proactive step towards comprehensive carbon accountability by planning to certify its TV series production with the Albert Calculator.

2.7 MACCs to show cost-effective abatement potential.

MACCs are useful summative tool to depict information representing the optimum potential managerial and technological carbon MMs (Eory et al., 2018). They are displayed in graphical format using a lineup of abatement measures organized by their individual costs per unit of carbon dioxide equivalent (CO_2eq) abated (Eory et al., 2018; Moran et al., 2010). These measures are established against the expected mitigation activities in a 'business as usual' (BAU) baseline (Eory et al., 2018; Moran et al., 2010). They offer a systematic, transparent, and cost-effective approach to setting emission reduction targets and formulating effective climate policies (McKitrick, 1999; Huang et al., 2016). The scope of the curve can be adjusted according to a region, country, industry or even the world, permitting widespread application over a variety of situations (Kesicki, 2010). To determine the efficacy and cost-effectiveness of various mitigation methods, this evaluative framework offers a methodological approach. This information helps with strategic decision-making during the creation of policies aimed at mitigating climate change (Kesicki, 2010).

2.7.1 Static, Expert-Based MACCs and the Bottom-Up Approach

Static MACCs consider existing carbon MMs to capture a specific moment in time, offering a limited perspective mainly focused on abatement and emissions variables (Timilsina et al., 2017; Guo et al., 2016). The static curve can be built using an expert-based approach which assesses individual carbon MMs, ranking them based on cost-effectiveness and associated emissions reduction potential (Kesicki, 2010; Kyprianidou et al., 2021).

Simultaneously, the bottom-up approach is instrumental in constructing the integrated static, expert-based MACC. It systematically incorporates present technologies into a comprehensive portfolio, subjecting them to a ranking system based on cost-effectiveness, albeit with potential oversight on broader economy-wide impacts (Huang et al., 2016). Stakeholders are specified as investors and the decision-making objective considers minimizing investment costs, the strategy mode is technology specific and information scope is static (Huang et al., 2016).

2.7.2 Economics of MMs within a MACC

MMs are measured on a carbon reduction and economic level. Therefore, determining economic feasibility of MMs is a crucial aspect in the development of a MACC. Specific cost measurement provides insight into the economics of MMs by indicating a detailed breakdown of the costs associated with respective components or activities (Schloemer et al., 2014). This outlines areas where costs are incurred, including the initial cost, operational expenses and anticipated revenues, therefore optimizing opportunity for potential cost reductions (Schloemer et al., 2014).

When evaluating the feasibility of these investment costs, it is common to consider the time value of money using economic measuring tools. One of them being the net present value (NPV) of the investment costs. NPV is an intelligent tool when making investment decisions because it gives an accurate representation of profitability and/or profit-loss over an investment period by taking inflation into consideration and applying a discount rate to the calculation (F.A. Chacra et al., 2005; Schloemer et al., 2014). This makes it beneficial for detailed decisions regarding budgeting and cost-control because it clarifies how changes in specific costs impact overall financial feasibility of an investment (Schloemer et al., 2014; F.A. Chacra et al., 2005).

2.7.3 Mitigation potential and the baseline scenario

Mitigation potential in the context of marginal abatement cost curves (MACCs) is based on comparing emissions from MMs to a baseline scenario. If specific mitigation actions are not implemented, the baseline acts as a benchmark and represents the expected trajectory of emissions (Wang et al., 2014). It is critical to establish a highly representative baseline for each abatement measure since results of cost-effectiveness highly depend on the carbon-abatement measure’s reference situation (Ibn-Mohammed et al., 2014). The effectiveness of mitigation strategies is evaluated by measuring the decrease in emissions that results from their application. The difference between baseline emissions and emissions under the effect of mitigation measures is the statistic used to determine mitigation potential (Ibn-Mohammed et al., 2014). The link between the cost of mitigation measures and the associated abatement levels is then visually depicted on the MACC, which quantifies the possible decrease in emissions.

The MACC explains mitigation potential by measuring the vertical distance between baseline emissions (Kesicki & Strachan, 2011). This distance represents the amount of possible emission reduction linked to the implementation of certain measures (Kesicki & Strachan, 2011). As a result, the MACC slope serves as a gauge for money needed to reduce emissions incrementally. The placement of alternatives on the MACC provides insight into the economic effectiveness of mitigation techniques (Ibn-Mohammed et al., 2014). Approaches that are more in line with the baseline are more economical and provide more possibility for mitigation at a lower expense (Hoffman et al., 2012).

2.7.4 Specific Costs Formula

This project's scope is specific to the film production phase (see Figure 1). Within this phase, the incorporation of MMs differs from traditional investment models, which makes considerations, like the project's lifetime and related discount rates, less relevant. Film production usually uses a rental model to apply MMs, in contrast to capital-intensive industries where the duration of investments greatly affects economic assessments.

With this in consideration a specific costs (C_{spec}) formula was built to negate the MMs lifetime as well as respective discount rates. The formula of which is elaborated on below and adapted from Blok & Evert Nieuwlaar (2016).

Formula 1:

$$Cspec = \frac{C^M - C^B}{ES}$$

Where:

- C is operational costs in MM (C^M) and in baseline (C^B) (euro/unit time)
- ES is the emission savings of the C^M vs the C^B (ton CO_2/unit time)

$$ES = 100 - (100) * \left\{\frac{E^M}{E^B}\right\}$$

This adjustment to the C_{spec} formula for the AV industry highlights how crucial it is to match analytical instruments with the characteristics of the sector to maximize the applicability of economic analyses in the context of reducing carbon emissions.

2.8 MACCs in the AV industry

Application of MACCs within the AV industry remains in its infancy, with one research project published by the FAF (Callebaut, 2022; Mohebi 2022). The research project was divided in two, where Callebaut (2022) performed the cost analysis of the MMs while, Mohebi (2022), quantified the emissions. The research scope was specific to the Flemish AV industry, analyzing six MMs including power supply, transport of goods, transport of crew, paperless office, vegetarian catering and local office set up (Callebaut, 2022; Mohebi 2022).

Their results exhibited that a power cabinet as an energy source was not cost-efficient considering the time and money it required to use, as well as the implementation of a paperless office (Callebaut, 2022; Mohebi 2022). These results will be closely considered in this research project when determining MMs for measurement.

3. Methodology

3.1 Research Design

The research employs a case study using a deductive approach to build a company-specific, bottom-up, expert-based MACC. Note that the focus of the MACC was based in the production phase of the AV production process, but data collection was taken throughout the pre-production period. Therefore, this project uses the logistics of the TV series as a model for analysis, where assumptions are leveraged from production data. The case study was split up into six main phases:

Phase 1. Identification of relevant MMs.
Phase 2. MMs in the context of the TV series.
Phase 3. BAU
Phase 4. MM details
Phase 5. Build MACC
Phase 6. Sensitivity analysis

Further details regarding data collection, analysis, and relevant assumptions are provided in the subsequent sections.

3.2 Phase 1. Identification of relevant MMs

3.2.1 Phase 1a Literature review

A semi-systematic literature review combined with snowball sampling using the following academic resource websites: google scholar, PubMed, research gate etc., was conducted to identify currently available MMs specific to the measure categories identified in the literature review. The search string exhibited in Table 1 was used to identify all the currently available MMs.

Table 1: Search string used to identify existing MMs

Topic	Search String	Explanation
Audio-Visual Industry	"audio-visual industry" AND (trends OR technologies)	This search aims to find information on current trends and technologies in the audio-visual industry.
Reducing Emissions in AV industry	"Reducing emissions" AND “audio-visual industry” AND (strategies OR techniques)	This search focuses on strategies and techniques for reducing emissions.
Carbon Reduction in AV industry	"Carbon reduction" AND (initiatives OR practices)	This search aims to find information on initiatives and practices related to carbon reduction.
Sustainability in AV industry	“sustainability” AND "audio-visual industry"	This narrows the search to sustainability practices

		specifically within the audio-visual industry.
Green Film Production	"Green film production" AND (practices initiatives)	This search focuses on practices and initiatives related to environmentally friendly or "green" film production.
Carbon Reduction Measures in the Film Industry	"Carbon reduction" AND “measures” AND "film industry"	This search is tailored to find specific measures related to carbon reduction in the film industry
Energy Efficiency on Film Set	"Energy efficiency" AND "film set"	This search specifically looks for practices related to energy efficiency on film sets
Efficient Generators for Film Production	“Efficient generators” AND "film production"	This search targets information on generators that are energy-efficient specifically in film production.
Green Generators for Film Production	"Green generators" AND "film production"	This search focuses on generators that are environmentally friendly in the context of film production.
Efficient transport in AV industry	“Efficient transport” AND “audio visual industry”	This search is designed to explore information on efficient transport practices within the audio-visual industry.
Sustainable Catering in AV industry	"Sustainable catering" AND “audio-visual industry”	This search focuses on finding information about sustainable catering practices.
Carbon Mitigation Innovations in Film Industry	"Carbon mitigation” AND/OR “innovations" AND "film industry"	This search targets innovations related to carbon mitigation specifically within the film industry.
Sustainable Set Design	"Sustainable set design"	This search aims to find information on sustainable practices in the design of film and TV sets.

3.2.2 Phase 1b MM grouping

Each of the MMs were grouped according to the measure categories they corresponded to. The measure categories included the impact areas identified in Section 2.3, Figure 3, which are repeated below:

1. Transport of crew
2. Transport of materials
3. On-set power
4. Office (heating/cooling/lighting)
5. Office waste reduction/sorting
6. On-set waste reduction
7. On-set waste sorting
8. Accommodation
9. Catering

MMs chosen for the MACC (see figure 5) were selected by passing them through the selection criteria below. Only MMs that responded “yes” to all 5 selection criteria were chosen for the analysis.

1. MMs need to be applicable to carbon intensive activities within production phase. ‘Carbon intensive’ can be defined as contributing to more than 5% of production emissions (de Souza et al., 2018).
2. MMs must be applicable to context of the AV production.
3. MMs that are estimated to have a high abatement potential (>2%) should be chosen. (Moran et al., 2010).
4. MMs with low data availability must be excluded (GHG Protocol, 2013).
5. MM must be feasible to analyze within the time constraints of this project.

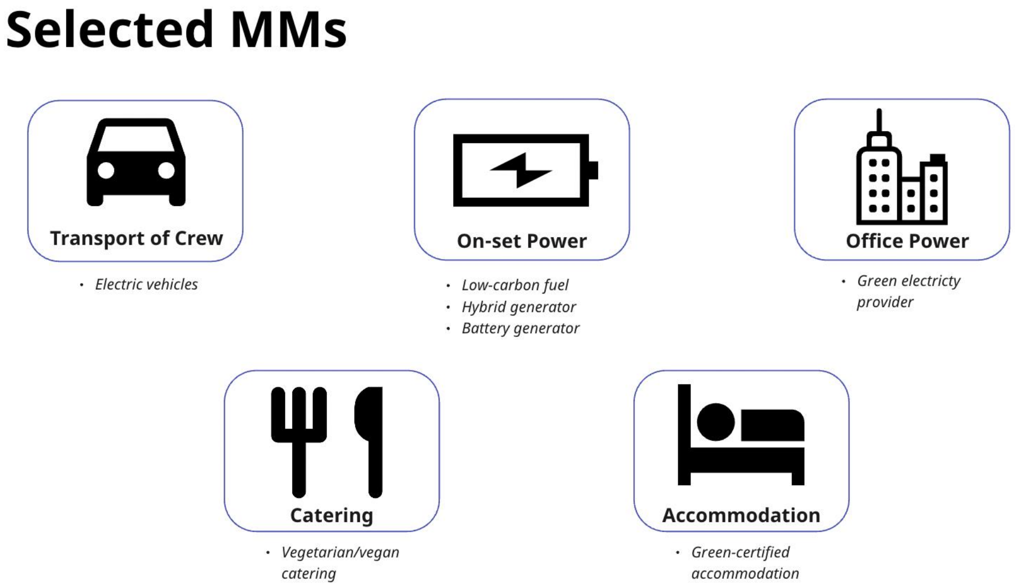

Figure 5: Measure categories and the selected MMs for further analysis

3.3 Measure Categories in the Context of Pupkin's tentpole production.

Each measure category was defined either through personal communication with industry professionals, or via desk research. Personal communication either took place through email correspondence, telephone calls or interpersonal meetings. This is specified for each in table 2.

Table 2: Data collection methods and the specific data needed for the measure categories in the context of the production

Measure Category	Data Collection Method	Data collected
Transport of Crew	• Personal communication via telephone call with a production assistant • Personal communication with the eco-manager and production assistants via email, telephone calls, or in-person meetings	• Understand daily transport logistics on set • Establish number of rented vehicles • Find out predicted distances covered by each vehicles
On-set Power (OsP)	• Desk research • Personal communication via email with hired gaffers	• Understand energy source requirements • Gain estimation on daily energy requirements

Measure Category	Data Collection Method	Data collected
Office Power	• Personal communication via in-person meetings with the eco-manager and email correspondence with the head of productions • Desk research on energy supply companies within the Netherlands • Further desk research on rankings of Dutch electricity providers based on their sustainable energy resources.	• Data for daily office energy use • Differentiate between grey and green electricity providers • Outline Dutch electricity providers on their level of adherence to green electricity provisions
Accommodation	• Personal communication with production assistants via phone call and email	• Understand logistics of booking accommodations with a multi-location production • Acquire information on number of individuals using hotels throughout production
Catering	• Personal communication with a production assistant via email	• Determine how cast and crew are fed each day • What type of meals are provisioned • The frequency of meals and how they differ each day

3.4 Baseline scenario

A baseline scenario was created for each of the 5 Measure categories. To ensure a representative comparison between the baseline and the MM, each baseline was built through desk research and validation with industry and academic professionals. The different baselines and their corresponding measure categories are outlined in Table 3. Each of the BAUs are outlined below, along with the relevant data assumptions.

Table 3: The scenarios studied and their respective BAU and MMs.

Measure categories	**BAU**
Transport of Crew	Diesel/petrol powered vehicles
On-set Power	Diesel generator
Office Power (electricity)	Grey electricity provider
Accommodation	Non-certified accommodation
Catering	Meat-based catering

3.4.1 Measure category 1: Transport of crew

The BAU was determined through personal communication via personal meeting with the eco-manager, and head of production. They concluded that the most representative BAU scenario would be the use of diesel/petrol-powered vehicles, reflecting the number of vans and cars rented by Pupkin.

Data assumptions

The estimated distances provided to obtain a quote from DIKS, a car rental company, were used to calculate the fuel requirements per vehicle and CO_2e emissions (see Table 4). This study assumes that these distances accurately reflect what occurred during the production period, so they were used to calculate the fuel use, charging frequency and CO_2 emissions for all the vehicles. The estimated distances were provided through a telephone call with the location manager and are shown in table 4 (Location manager, personal communication, August 18, 2023).

The vehicles chosen for analysis were selected based on the seating capacity required on-set and cost. Seating capacity was determined based on communication with Pupkin representatives, where each van had to fit 7 persons, and each passenger and PA car had to fit 5. Associated rental costs were assured to be the lowest. The chosen vehicles included the diesel-powered Mercedes Sprinter (Double Cabin) for the 8 vans and the petrol-powered Nissan Micra [B] for the 4 other cars and 4 PA cars (DIKS, 2023).

DIKS' website does not automatically generate quotes for periods longer than 30 days (DIKS, 2023) so, this study assumed the daily rental cost from the 30-day period multiplied across the entire shooting period (126 days) would be an accurate representation for analysis. Costs for each of the vehicles can be observed in Table 5.

Table 4: Estimated total distance covered by each vehicle throughout the production period.

Type of vehicle	Distance covered by all vehicles (km)

x8 vans	192,000
x4 Other cars	9,600
x4 PA cars	160,000

Table 5: Vehicle type and associated costs for entire shooting period

Amount of vehicles	**Vehicle type**	**Daily rental price per vehicle (€)**	**Total rental price per vehicle type (DIKS, 2023) (€)**
8	Merecedes Sprinter (double cabin)	135.00	136080.00
4 (PA cars)	Nissan Micra [B]	55.00	27720.00
4 (other)	Nissan Micra [B]	55.00	27720.00
		Total rental price of all vehicles (€)	191520.00

Fuel usage and associated costs also had to be estimated using both the distances provided by Pupkin (Table 4) and fuel consumption rates of chosen vehicles. The fuel consumption rates for both vehicle types were acquired from respective vehicle type's company websites and can be observed in Table 7 (Mercedes, 2018; Nissan, 2023). Petrol and diesel prices were also acquired through desk research (refer to Table 6) (Globalpetrolprices, 2023; Centraal Bureau, 2023). Estimations for fuel requirements and associated costs can also be seen in Table 5.

Emissions for each of the cars were calculated using the Albert Calculator, which adjusts emissions according to vehicle type, engine size, fuel type and the amount of fuel used per vehicle. The calculator uses the formula below to calculate emissions associate with road transport.

Formula 2 (Albert, 2022b)

Specific Fuel Type Regular taxi emission factor (kg CO_2e/ km or mile) = average car (large/ medium) specific to fuel type emission factor x 1.4 (Uplift factor)[1]

Table 6: Petrol and diesel prices used to estimate fuel consumption and associated costs.

Type of fuel	**Fuel price (€/L)**
Petrol	2.110
Diesel	1.809

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[1] This is an adjustment factor which accounts for any unaccounted uncertainties or additional factors not considered in initial calculations (Transport for London, 2022)

Table 7: Fuel consumption requirements and associated costs (DIKS, 2023).

Vehicle type		**Fuel consumption rate (L/100km)**	**Predicted distance travelled (km)**	**Total fuel used (L)**	**Fuel consumption costs (€)**
Mercedes sprinter (Double Cabin)		9.1	192000	17472	31606.84
Nissan Micra [B]	Other	5.01	9600	480.96	1014.82
	PA car	5.01	160000	8016	16913.76
				Total (€)	**49535.43**

3.4.2 Measure category 2: On-set power

After consultation with Pupkin representatives including the production's location manager, eco-manager, head of productions, and Line the on-set power BAU was decided to be a single 60kVa diesel-powered generator.

Data assumptions

Pupkin sourced their generator from rental company, Het Licht, therefore rental costs were derived from email and telephone correspondence with Het Licht representative (refer to Table 8), (Het Licht representative, personal communication, August 7, 2023). Het Licht also provided the fuel consumption of their truck to transport the generator to and from different locations, which was averaged out to 30L/100km (Het Licht representative, personal communication, August 7, 2023). The total distance between locations was estimated by mapping all the shooting locations according to the three Blocks. Figures 6,7,8, show the routes that were taken between each of the shooting locations, Table 8, shows the total distance travelled. Based on the total distance travelled between each shooting location and the assumed fuel consumption of Het Licht's truck the total fuel consumption was calculated as 426.6L of diesel (refer to table 8).

Table 8: Key values for baseline calculation

Total shooting period (days)	**Actual shooting period (days)**	**Rental costs/day (€)**	**Fuel requirement/day (L)**	**Diesel price (€/L)**	**Total distance between shooting locations (km)**	**Fuel consumption of truck (L)**
126	58	250	30	1.809	1422	426.6

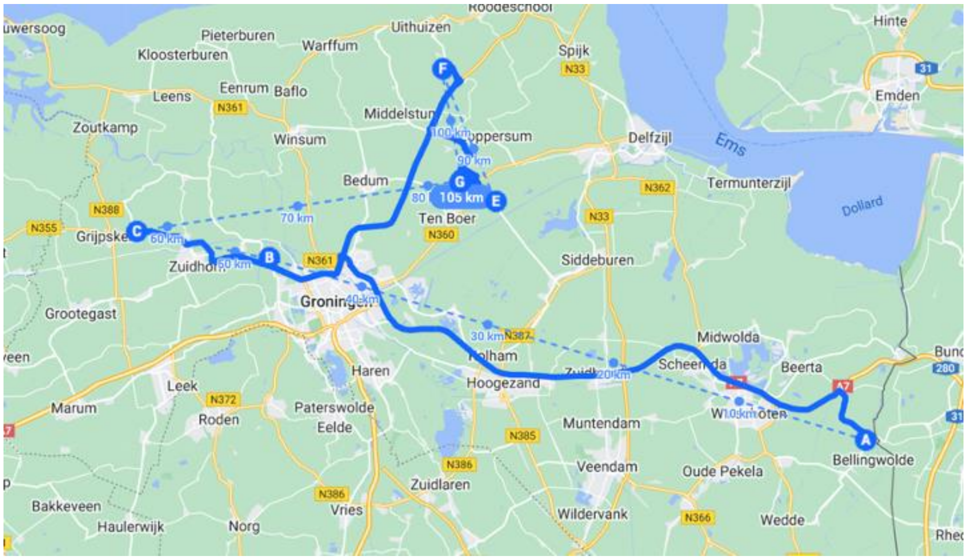

Figure 6: Map showing all transport distances required in Block 1.

Figure 7: Map showing all transport distances required in Block 2

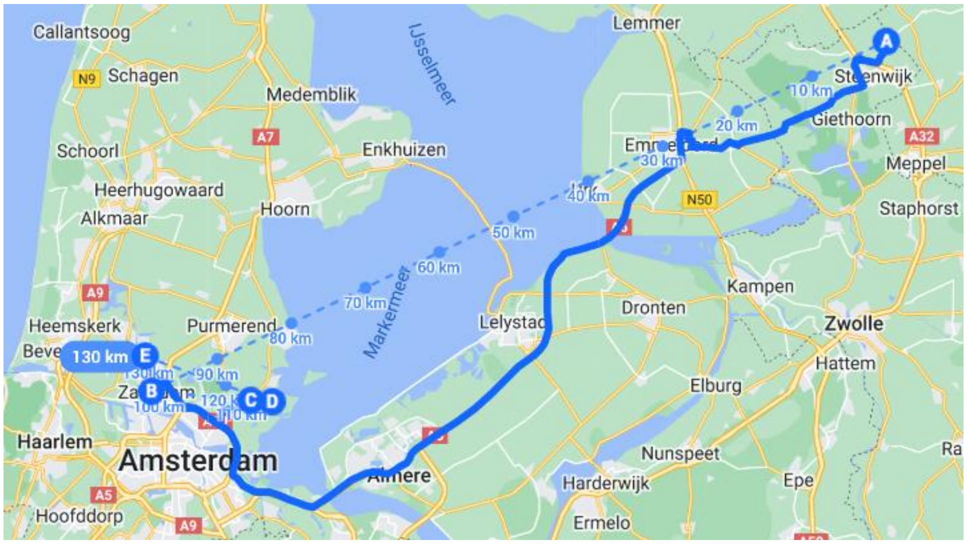

Figure 8: Map showing all transport distances required in Block 3

The generator's fuel requirements per day were provided by the location manager, who noted that the power draw is shooting day dependent (Location manager, personal communication, August 9, 2023). Energy requirements for lights would increase if the shoot was taking place at night, if more takes were required than expected, if more electrical equipment was needed compared to another day (Location manager, personal communication, August 9, 2021).

An estimated daily fuel requirement for the generator was provided considering that the 60kVa generator has an average fuel consumption of 5L diesel per hour and a shooting day is 10.25 hours (Location manager, personal communication, August 9, 2023). However, the generator is not running on maximum load every hour of the day, so it was assumed that 30L of diesel was required per shooting day (Location manager, personal communication, August 9, 2023). The average diesel price per liter in the Netherlands was provided by the Central Bureau (2023) (refer to table 8).

Carbon emissions were expressed in t CO_2e which were derived from the Albert Calculator (Albert, 2023). The Albert Calculator sources national equivalent well-to-tank (WTT) emission factors for emission calculation (Albert 2022b). Carbon emissions from the direct use of the generator are accounted for, as well as those from the transport of the generator from one location to the next. Refer to Figures 6,7,8 for total distances travelled in each shooting Block.

3.4.3 Measure category 3: Office Power

The BAU scenario for energy in office includes sourcing electricity from an unsustainable electricity provider defined by WISE (2021).

Data assumptions

Pupkin's office manager provided the average annual power consumption of the office which was input into the energy supplier company websites to obtain a monthly quote (Office manager, personal communication, August 17, 2023). The three lowest ranking energy suppliers (refer to Figure 5) were used for data collection. However, some energy companies had to be excluded because they only provided gas (Next Energy, 2020), they did not provide energy to large scale consumers (Coolblue Energy, 2023; United consumers, 2023), others do not operate anymore (Qwint) and others did not offer online estimations (Naked Energy, 2022). Refer to table 9 to observe the 3 chosen energy suppliers.

An average monthly price was taken across the three energy supplier companies. This was then extended to over the whole shooting period, 126 days, equivalent to 4 months. Table 9 also exhibits the monthly prices per energy company and their overall average monthly price.

The Albert Calculator was used to calculate emissions by using the Chartered Institution of Building Services Engineers (CIBSE) benchmarking tool to allocate benchmarks for four different office types (Albert 2022b). The type chosen for this calculation included *Air-conditioned* *(prestige/HQ)*. The data is taken for a calendar year rather than a working year and multiplied by country dependent emission factors, see formula below for data requirements (Albert, 2022b).

Formula 3 (Albert, 2022b)

Emissions associated with Production Office (tCO_2e) *= [(Benchmark x # full time equivalent employees*[2] *x #number of days) x emissions factor for electricity and gas)] / 1000*

Table 9: Monthly energy prices and chosen energy suppliers for analysis of BAU.

Energy Provider	**Innova Energy**	**Energie Direct**	**Clean Energy**	**Average monthly price (€)**
Monthly fee **(**€)	449.81	413.00	399.26	420.69

3.4.4 Measure category 4: Accommodation

The BAU was built based on accommodation requirements in the TV series and consultation with industry professionals including Pupkin's Head of Productions and the hired eco-manager for the production. Normally, the production company would seek out hotels based on their vicinity to the shooting locations while also considering costs that were feasible when considering the budget. Sustainable certification of the hotel would not be a deciding factor when choosing accommodation, therefore the BAU scenario was based on choosing hotels which were uncertified and within an appropriate distance from the shooting locations in each block.

Data assumptions

This study assumes a total amount of 2 people per room for each hotel. This would not be the case for the actual production because some staff/crew would request a single room for themselves. Costs for each hotel were taken from each of the hotel company's websites (Mercure, 2019; Olympic Hotel, 2024). Prices covering all the nights and rooms for each block could not be generated automatically on the company websites due to the large number of rooms required. Therefore, the price for one room over one night was taken and extrapolated over the shooting period for each block (Table 10).

The hotel locations were broken down as depicted in table 10. The table also shows the costs per night, the number of rooms, and the number of nights booked for each block. The hotel

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[2] There is a total of 6 full time equivalent employees working on the TV series within the office

chosen for the first block was the one chosen for the production, the other two were determined through desk research.

Table 10: Cost data relevant to each shooting block and accommodation.

Shooting block	**Location**	**Hotel names**	**Costs per night (€)**	**Number of rooms**	**Number of nights**	**Total Cost (€)**
1	Groningen	Mercure Hotel Groningen	141	20	20	56400.00
2	Amsterdam	Olympic hotel	143	20	21	60060.00
3	Groningen	Mercure Hotel Groningen	141	20	17	47940.00
					Total costs over shooting blocks (€)	**164400.00**

Emissions associated with the intensity of accommodation use were generated through the Albert Calculator. The calculator characterizes accommodation based on their type and calculates emissions based on the average electricity consumption of the accommodation type based on the Energy Star site (see Table 11) (Albert, 2022b). The calculator combines the energy consumption benchmarks with the Cornell Hotel Sustainability benchmarking index and multiplies them by the relevant electricity carbon factor for each country. In the case of the Netherlands, this is 0.523kg CO_2e per kWh (Albert, 2022b; Climate Neutral Group, 2022). The baseline uses the average electricity consumption for the Luxury hotel accommodation. Emissions for each hotel are found in table 12.

Table 11: Classification of electricity consumption and accommodation type

Accommodation type	**Electricity consumption (kWh/day)**
Economy hotel	15.11
Midscale hotel	29.78
Upscale hotel	34.51
Luxury hotel	45.08
Apartment/condo/flat	31.01
Average house	17.47
Large house	47.94

Table 12: Emission data for each shooting block and accommodation.

Shooting block	**Accommodation name**	**Emissions (tCO_2eq)**
1	Mercure Hotel Groningen	5.41
2	Olympic Hotel	5.68
3	Mercure Hotel Groningen	4.6
	Total emissions (tCO_2eq)	**15.69**

3.4.5 Measure category 5: Catering

Desk research and consultation with industry professionals concluded that traditionally, cast and crew are given meals where meat is the main source of protein, if they are vegetarian or vegan, they are allowed to choose a vegetarian option according to their dietary requirements (Callebaut, 2022; Mohebi, 2022). This study takes an all-meat catering service as the BAU for Measure category 5. This includes fish, pork, chicken, lamb and beef proteins provided throughout the production.

Data assumptions

As specified in Measure category 4, the amount of people on set is dependent on the shoot, so an average of 40 people on set each day is taken for this study. This means that across 58 shooting days 2320 meals are served.

Costs were determined through desk research since the catering company hired for the TV series could not provide any. Catering companies were identified by using the following search terms “lunch catering”, “catering Netherlands” and “catering to hire”. Selection criteria included companies which provided both vegetarian and meat options with associated prices for each meal type. A total of 4 catering companies were used for the analysis (Delight, 2023; Happie delivery, 2023; Eurest, 2023; Lunchidee, 2023). More catering companies were available, but they could only provide cost differences upon requesting a quote, which was not possible in the time limits of this study. A cost per person/meal was used for all the meat-based meal types and an average cost per company was taken (see table 13). This was multiplied across 2320 meals. Finally, the total average cost from the four catering companies was taken as the total for the specific cost calculation. Refer to table 13 for the complete breakdown of costs per company and the total average costs.

Emissions are calculated using the Albert Calculator which uses EFs for different food types from various food LCAs from food suppliers, consultancy firms and food emission resources to generate emission benchmarks for different meal types (Albert, 2022b; PHEFSA, 2017; Poore & Nemecek, 2018; Clune et al., 2017; Ritchie et al., 2020). To establish the emission benchmark, an average portion consumption was based a National Diet and Nutrition survey, with a meal benchmark of a 2500 calorie diet, assuming calorie intake is enough to maintain current weight (Albert, 2022b). See Appendix D, table X for Albert's meal type characterization and respective benchmarks.

The study assumes an average of all the different protein types for the emission calculation. This means that 2320 meals of each protein type were taken and averaged out for the emission calculation, the data for this is shown in table 13b.

Table 13: Cost data from four catering companies

Catering service provider	**Meal type**	**Cost/meal type (€)**	**Average cost of meal/ company (€)**	**Total cost (€)**
Delight catering service	Sandwich (meat)	3.85	4.38	10150.00
	Salad (meat/fish)	4.95		
	Quiche (meat/fish)	4.75		
	Soup (meat)	3.95		
Happie delivery	Ham sandwich	4.95	4.62	10723.55556
	Roast beef sandwich	5.50		
	Tuna melt	4.95		
	Smoked salmon sandwich	5.95		
	Smoked salmon salad	4.55		
	Carpaccio salad	4.25		
	Tuna salad	3.95		

Catering service provider	**Meal type**	**Cost/meal type (€)**	**Average cost of meal/ company (€)**	**Total cost (€)**
	Carpaccio wrap	3.75		
	Smoked salmon wrap	3.75		
Eurest	Basic lunch to go package	6.16	8.20	19035.6
	Lunch basic	10.25		
Lunchidee	Club sandwich	5.0	5.65	13102.20
	Chicken wrap	4.59		
	Chicken sandwich	6.50		
	Meatball sandwich	6.50		
			Average total cost (€):	**13252.83**

Table 13b: Emission data for all meat protein types

Protein type	**Albert benchmark (kg CO_2e/meal)**	**Carbon emissions (tCO_2eq)**	
Fish	2.49	5.78	
Beef	9.90	22.97	
Lamb	5.22	12.11	
Chicken	2.88	6.68	
Pork	3.14	7.28	
		Average emissions (tCO_2eq):	**10.96**

3.5 MMs

The selected MMs were then adjusted within the context of the TV series by directly comparing them to their BAU, and confirming the outcome with Pupkin representatives, and other industry professionals. MMs specific to their impact categories are outlined in Table 14. Each of the MMs and their relevant data assumptions are outlined in the upcoming sections.

Table 14: The scenarios studied and their respective BAU and MMs.

Measure categories	BAU	MMs
Transport of Crew	ICE vehicles	Electric vehicles
On-set Power	Diesel generator	Generator with low-carbon fuel
		Hybrid generator
		Battery powered generator
Office Power (electricity)	Grey electricity provider	Green electricity provider
Accommodation	Non-certified accommodation	Green-key certified
Catering	Meat-based catering	Vegetarian catering

3.5.1 Measure category 1: Transport of Crew

The diesel/petrol powered vehicles were replaced by electric vehicles based on what was available to rent on DIKS' website (DIKS, 2023). This choice was made through desk research (European Commission, 2021; Lupu et al., 2023; Rudenauer et al., 2021; GPG, 2023) and confirmation with the on-set eco-manager as well as an external eco-manager through personal communication.

Data assumptions

The electric vehicles were chosen based on the same selection criteria issued by Pupkin for the BAU scenario; seating capacity and cost. The Mercedes EQV [vive] was selected to replace the Mercedes Sprinter (Double Cabin), but the number of passenger cars was adjusted according to the EQV's seating to ensure a lower financial spend (DIKS, 2023). The Mercedes Sprinter (Double Cabin) only had 7 seats, when multiplied across 8 vehicles created 56 spaces, while the EQV had 8 spaces. Therefore, only 7 Mercedes EQV [vive] vehicles were required for the same number of seats. The Peugeot E-208 [BE] was chosen to replace the Nissan Micra [B] since it had the same seating capacity and the lowest cost compared to other electric alternatives (DIKS, 2023). The same number of Peugeot E-208 [BE] vehicles was used in the analysis due to both offering the same seating capacity. Rental costs for each vehicle were acquired from DIKS' company website, so the costs were calculated using the same assumption as the BAU. Refer to Table 13 to see the cost breakdown over the shooting period.

Charging costs were also included by using the monthly recharging price calculator, an automatic calculator issued by the European Commission (European Commission, 2022). The calculator is country specific and is calculated using average consumption (kWh/100km), the monthly distance driven, the ratio of private and public recharging, and within public recharging the expected share between slow (AC) and fast (DC) recharging sessions (European Commission, 2022).

The calculator only permitted a maximum of 10,000km to be driven per month, therefore costs were extrapolated according to the total assumed distances travelled by each vehicle (refer to Table 15). Average consumption for both vehicle types were retrieved from the electric vehicle (EV) database (2022). The ratio between public and private home charging was assumed to be 100% public because only one shooting location will be based in Amsterdam, where Pupkin home offices are located. The rest of the locations are scattered throughout Groningen, Arnhem, Haarlem, Utrecht and Leiden (refer to Figures 6,7,8). The ratio between the slow (AC) and fast (DC) charging was assumed to be 50/50, this would fluctuate during shooting and will be accounted for in the sensitivity analysis. Charging cost data can be observed in Table 16.

The total distance travelled by the Mercedes EQV [vive] was adjusted according to 7 vehicles instead of 8. The total distance covered by 8 Mercedes Sprinter (Double Cabin) vehicles was 192,000km, since it was assumed by Pupkin that all vehicles would travel equal amounts, the total distance was adjusted per vehicle, which is equal to 24,000km. Therefore, the total distance covered by the Mercedes EQV [vive] was assumed to be 168,000km[3].

Emissions were calculated using the Albert Calculator, vehicle size was adjusted according to the BAU.

Table 15: Rental costs over shooting period

Number of vehicles	**Vehicle type**	**Daily rental price per vehicle (€)**	**Total rental price per vehicle type (€)[4]**
7	Merecedes EQV [vive]	165	145530
4 (PA cars)	Peugeot E-208 [BE]	55	55440
4 (other)	Peugeot E-208 [BE]	55	27720
		Total rental price of all vehicles (€)	**200970**

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[3] 24,000km*7 vehicles = 168,000km

[4] The rental price is multiplied across the total amount of vehicles in each section.

Table 16: Data used to calculate charging costs per vehicle.

Vehicle Type		Total distance over shooting period (km)	Average consumption (kwh/100km)	Recharging cost per 10000km (€/10000km)	Total km/10000 km	Total charging cost/vehicle type (€)
Mercedes EQV		168,000	29	1683	16.8	28274.4
Peugeot e-208	**Other cars**	9,600	16.2	/	/	891
	PA cars	160,000	16.2	891	16	14256
					Total charging price for all vehicles (€)	**43421.4**

3.5.2 Measure category 2: On-set Power

3.5.2.1 Low-carbon fuel

This involved the rental of a traditional diesel-powered generator, but the diesel was replaced with 100% hydrated vegetable oil (HVO100). This MM was identified through desk research and advice from the rental company, Het Licht, who also provided the HVO100 fuel (Het Licht representative, personal communication, August 7, 2023; Victory, 2015; KZN Film Commission 2020; Albert 202; Lupu et al. 2023 GPG, 2023).

Data assumptions

This MM assumes an equal energy requirement as the BAU, rental costs were also assumed to be the same as those provided by Het Licht representative via email and phone call (Het Licht representative, personal communication, August 7, 2023). Fuel requirements were also assumed to be the same as those advised by Pupkin's location manager (30L) (Location manager, personal communication, August 9, 2021). Additionally, the fuel required to transport the generator was also assumed to be equal to that of the BAU.

Fuel price/liter were retrieved from FullTank (2023), which can be found in table 17 and the Albert Calculator was used to calculate carbon emissions.

Table 17: Key value for MM calculation

HVO100 fuel price (€/L)
2.0851

3.5.2.2 Hybrid Generator

Desk research provided that the Hybrid solar battery and bio-fuel generator would be a viable sustainable alternative energy source on set to the diesel generator.

Data assumptions

Rental company, Volta Energy, suggested renting their 15kVA hybrid generator according to the energy requirements (non-constant 12kWH for 10.25 hours) described by the location manager via email correspondence (Location manager, personal communication, August 18, 2023; Het Licht representative, personal communication, August 9, 2021). Volta Energy representative provided a weekly rental quote for the 15kVA generator, which included the additional bio-fuel costs (refer to Table 18). Volta Energy also provided transportation costs which include the costs associated with transporting the hybrid generator to the first shooting location and from the final shooting destination back to their headquarters (refer to Table 18) (Volta Energy representative, personal communication, August 18, 2023). They could not provide the additional costs associated with transporting the hybrid generator between all the shooting locations, so the additional costs associated with transporting the generator were assumed to be the same as that of the BAU.

Table 18: Cost values provided by correspondence with Het Licht

Weekly rental cost (€)	**Daily rental cost (€)[5]**	**Transportation costs (€)**
520.17	74.31	377.64

The Albert Calculator does not have an option to calculate emissions for hybrid generators, so this data was requested from Volta Energy via email. A representative sent emissions relevant to the 15 kVA generator over a period of 62 days, spanning over the months with lowest amount of sun hours, with a load of 70% (Volta Energy representative, personal communication, August 18, 2023). The data is shown in Table 19 as well as in Appendix F, Figure X.

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[5] Daily rental cost calculation: weekly rental cost (520.17)/7 days = 74.31

Table 19: Emission calculation values for Hybrid generator.

Emission data provided by Volta energy	
Emissions from bio-diesel gen-set (tCO_2eq) over 62 days	1.38974
Emissions from backup generator (tCO_2eq) over 62 days	0.01809
Emissions from solar generator (tCO_2eq) over 62 days	0.00296[6]
Total emissions (tCO_2eq) over 62 days	1.41079
Emissions from hybrid generator per day (tCO_2eq)	0.02275[7]

3.5.2.3 Battery powered generator

Rudenauer et al. (2021), GPG (2023) and SKOON (2022) all highlighted the use of a battery powered generator as an energy source on set.

Data assumptions

Based on energy requirements provided by Pupkin's location manager, an energy alternative was suggested by a representative at rental database, SKOON, through email correspondence (SKOON representative, personal communication, August 15, 2023). The required power capacity was detailed as 12kWh for 10.25 hours at a non-constant rate (Location manager, personal communication, August 9, 2021). The SKOON representative suggested a 45KW/80kWh battery trailer and provided the daily rental costs and the company's transportation costs, which considered transporting the battery to the first shooting location and back to the rental company from the final shooting location. The rental company could not provide additional costs of transport between shooting locations, so costs were assumed to be the same as those used to transport the diesel generator in the BAU. Charging costs were calculated by multiplying the cost intensity of a kWh in the Netherlands against the energy consumption of the battery when charging it. All cost data is shown in table 20.

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[6] Calculation: Emissions from bio-diesel gen-set + emissions from back-up generator + emissions from solar generator

[7] Calculation: Total emissions (1.41079 t CO_2eq)/62 days.

Table 20: Cost values for MM calculation

Daily rental cost (€)	**Transportation costs provided by SKOON (€)**	**Transportation costs from the BAU (€)**	**Cost intensity of kWh (€/kWh)**
136.56	400	771.72	0.475

Emissions for charging the battery were calculated manually because the Albert calculator lacks this feature. This study assumes that the battery was charged after every shooting day to its full capacity to prepare it for the next shooting day. Therefore, the battery was charged 57 times. The battery type's energy consumption was used to calculate its respective daily energy consumption. Note that the study assumes the battery will be charged from grey electricity sources, this could vary during actual production depending on the type of electricity provided at the charging stations located close to the shooting locations. The key values for the calculations are found in Table 21 and their sources are listed below the table. The formulas for each are elaborated below.

Table 21: Key values for battery emission calculation

Battery capacity (kWh) (1)[8]	**Charging efficiency (%) (1)**	**Grey electricity emission factor (kgCO_2/kWh) (2)**
87.5	80	0.523

Source key: (1) SKOON, 2023; (2) Climate Neutral Group, 2022

<u>Formula 4: Energy consumption</u>

Energy consumption = Battery Capacity/ Charging Efficiency

Energy consumption = 109.38kWh

<u>Forumla 5: Emissions</u>

Emissions = (Energy consumption*Emission factor of grey electricity) *57 charging sessions

Emissions = 3260kgCO_2

Emissions = 3.26tCO_2

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[8] The numbers correlate to the source the value was derived from, which are listed below the table.

3.5.3 Measure category 3: Office power

A switch to a renewable energy provider was recommended by various academic papers and online resources (European Commission, 2023; Rudenauer et al., 2021; Albert, 2020).

Data assumptions

Green energy suppliers were chosen based on a comparative study carried out by WISE (2021), which ranked Dutch energy suppliers based on their share of green and grey electricity (refer to Figure 9). Suppliers which scored 8 or higher are actively transitioning into a sustainable energy supply, either by investing into green energy resources themselves or buying it from a green energy supplier (WISE, 2021). Suppliers lower than 5.5 do not make any contribution to transitioning towards green energy, they usually have grey purchasing power from wholesale markets and resupply it to their customers (WISE, 2021).

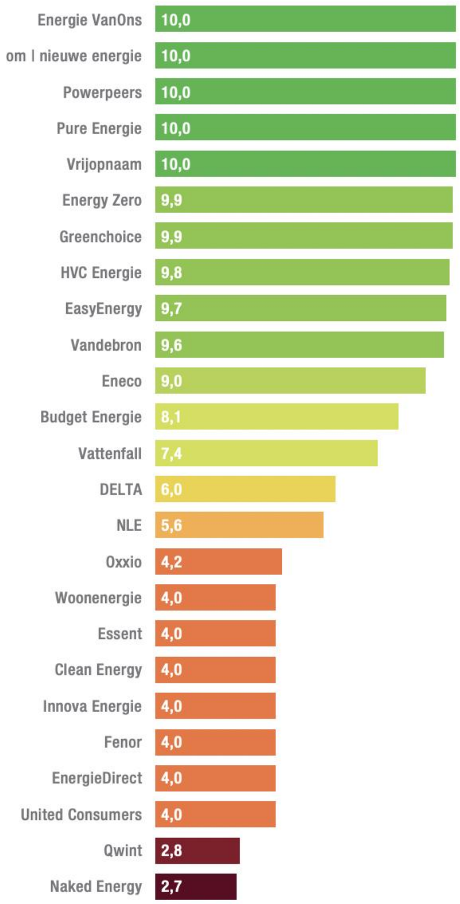

Figure 9: Ranking of Dutch energy suppliers based on share of green and grey electricity (WISE, 2021).

The same energy consumption provided by the office manager for the BAU was also used in the MM calculation when retrieving monthly quotes from energy supplier websites (Office manager, personal communication via telephone call, August 15, 2023). The three highest ranking energy suppliers depicted in Figure 5 were chosen for this analysis. Note that some energy suppliers had to be excluded from the analysis because they did not take on larger consumers (Energie VanOns, 2023), others were excluded because they did not provide online estimations of monthly prices unless registered as a consumer (HVC, 2023; easyEnergy, 2023; Energy Zero, 2023).

As done in the BAU, an average monthly price was considered across the three chosen energy suppliers. Monthly prices were only considered throughout the shooting period, 126 days, equivalent to 4 months.

The Albert Calculator was used to calculate emissions associated with green energy providers in office. The same principles apply as mentioned in the BAU for Measure Category 3. The calculator assumes a fully renewable source of energy so emissions are accounted as 0tCO_2e (Albert, 2022b).

3.5.4 Measure category 4: Accommodation

The MM for Measure category 4 included booking hotels with the Greek-Key certification (Lopera-Marmol & Jimenez-Morales 2021; Albert 2021; Rudenauer et al.,2022). Green-key is an eco-label certification program that assesses and certifies hotels for their commitment to sustainability (Green Key, 2023). The certification process involves a comprehensive evaluation of various aspects of a hotel's operations and management (Green Key, 2023). These include a holistic overview of sustainable elements such as energy efficiency, water conservation, waste management, green building design and others (Green Key, 2023).

Green-key uses a point-based system to assess these, and a company is scored based on their adherence to the eco-label's standards (Green Key, 2023). Hotels that meet the required criteria and achieve a minimum point threshold are awarded Green Key certification at one of four levels: Bronze, Silver, Gold, or Platinum (Green Key, 2023). This study only includes hotels ranked on a Gold level.

Data assumptions

The MM for Measure category 5 assumes the same amount of hotel residents as done in the BAU; 2 people per room for an average of 40 people per night. Cost data for each hotel was also taken from the company websites and extrapolated across the three shooting blocks based on the price of one hotel room for one night. The costs for each hotel in each shooting block is exhibited in table 22.

Table 22: Cost data relevant to each shooting block and accommodation.

Shooting block	**Location**	**Hotel names**	**Costs per night (€)**	**Number of rooms**	**Number of nights**	**Total Cost (€)**
1	Groningen	Flonk Hotel Groningen	126	20	20	94080.00
2	Amsterdam	Conscious Hotel Westerpark	224	20	21	50400.00
3	Groningen	Flonk Hotel Groningen	126	20	17	42840.00
					Total costs over shooting blocks (€)	**187320.00**

Emissions for the MM were also calculated using the Albert calculator, but the calculator assumes that the certified accommodation makes use of 100% renewable electricity and therefore will produce 0 tCO_2eq (Albert, 2022b). The uncertainty of this parameter is addressed in the sensitivity analysis below.

3.5.5 Measure category 5: Catering

After discussing with Pupkin representatives including the Eco-manager and head of productions it was decided that an accurate MM for this scenario would be catering vegan or vegetarian meals throughout production.

Data assumptions

The same number of meals were used as in the BAU, for an average 40 people on set throughout the 58 shooting days, totaling 2320 meals.

Costs were evaluated in the same way as the BAU and can be seen in Table 23.

Emissions were also calculated using the Albert Calculator which had data options for both vegan and vegetarian meals. Emissions were calculated by assuming the same amount for each meal type, 2320 meals for 58 days, and taking an average from both. This data is shown in Table 24.

Table 23 - Cost data from four catering companies

Catering service provider	**Meal type**	**Cost/meal type (€)**	**Average cost of meal/ company (€)**	**Total cost (€)**
Delight catering service	Sandwich (meat)	3.85	4.38	10150.00
	Salad (meat/fish)	4.95		
	Quiche (meat/fish)	4.75		
	Soup (meat)	3.95		
Happie delivery	Hummus sandwich	4.95	4.51	10463.20
	Vegan chicken sandwich	5.95		
	Pasta salad	4.25		
	Caprese salad	3.95		
	Greek salad	3.45		
	Vegan chicken wrap	3,75		
Eurest (UU catering)	Zero food waste vegetarian package	9.37	9.43	21885.33
	Lunch package to go vegan	7.39		
	Vegan lunch	11.54		
Lunchidee	Club sandwich vegetarian	5.00	5.27	12232.20
	Hummus wrap	4.59		
	Focaccia grilled zucchini	5.00		
	Mozzarella sandwich	6.50		
			Total average (€):	**13682.68**

Table 24: Emission data for vegetarian and vegan meals.

Protein type	**Albert benchmark (kgCO$_2$e/meal)**	**Carbon emissions (tCO$_2$eq)**
Vegetarian	**0.76**	**1.76**
Vegan	**0.53**	**1.33**
		Average (tCO$_2$eq): **1.49**

3.6 Build MACC

The data required to build the MACC are detailed and explained in Appendix A, Table 2. This data was used to calculate the specific costs for each MM using Formula 1 (see Section 2.7.4). The MACC-Global calculator (2024) was used to build the curve by inputting the abated costs and emissions for each MM.

3.7 Sensitivity analysis

A sensitivity analysis was performed based on assumptions made throughout data collection and will involve systematic change of influential parameters. This will depict how results may differ according to adjustments in parameters which were uncertain. Note that parameters were adjusted singularly and not in conjunction with another influential parameter. Uncertain parameters are described in each Measure category below.

3.7.1 Measure category 1: Transport of cast/crew

A best-worst case sensitivity analysis was performed for the uncertain parameters in Measure category 1 to gain a comprehensive understanding of potential outcomes under different circumstances (Gamble & Hollis, 2005). This Measure category evaluates the difference in technological efficiency and does not focus on establishing a more efficient transport plan based on logistics. Therefore, even though travel distance varies across productions, these differences will not be assessed in the sensitivity analysis as they are not relevant to this context.

The initial analysis used data from a single rental company based in the Netherlands, DIKS. This limited the chosen vehicles to those that were provided by DIKS. Other Dutch production companies may choose different rental vehicle companies which offer different vehicles at varying price ranges. The vehicles also had different consumption rates which would affect the total fuel cost or charging cost at the end of the shooting period. Therefore, this project takes variance in cost and fuel/energy consumption rate into consideration by using resources from six car rental companies operating in the Netherlands (SIXT, 2023; Enterprise.nl, 2023; Europcar, 2023; Hertz, 2023; DIKS, 2023; Oscar, 2023). The best-case scenario refers to the lowest costs referring to rental prices and fuel costs based on lower consumption rates. While the worst-case scenario takes the highest costs into consideration. The study also considers the significance in price range from using public vs. private charging ports throughout the Netherlands.

3.7.1.1 Best- and worst-case scenario: Rental cost parameter

This section details the best-case scenario for the rental costs' parameter being the lowest rental costs from the six car rental companies as well as the worst-case scenario, which represents the highest costs from the car rental companies. These were taken for both the BAU, diesel/petrol vehicles and the MM, electric vehicles. The best-case scenario for BAU rental costs are detailed in Table 25, and for the MM in Table 26. The worst-case, being the highest rental costs for the BUA are exhibited in Table 27 and for the MM in Table 28. Note that certain rental companies did not offer certain vehicle types, so a "/" was used to represent a lack of data.

Table 25: Best-case scenario for BAU rental costs

Rental company	Vehicle type	Vehicle name	Cost/day (€)
SIXT	Passenger car	Opel Mokka	54
	Van	Mercedes-Benz vito	64.33
Enterprise .nl	Passenger car	Opel Corsa	57.74
	Van	/	/
Europcar	Passenger car	Renault Clio 1.0	62.99
	Van	VW T6 minibus long 2.0 TDI	174.91
Hertz	Passenger car	Opel Corsa	82.17
	Van	/	/
DIKS	Passenger	Nissan Micra [B]	55
	Van	Mercedes Sprinter	135

Rental company	Vehicle type	Vehicle name	Cost/day (€)
Oscar	Passenger	Hyundai i10	25
	Van	VW Multivan	120

Table 26: Best-case scenario for MM rental costs

Rental company	Vehicle type	Vehicle name	Cost/day (€)
SIXT	Van	Mercedes Benz e-vito	64.33
	Passenger car	Kia e-niro	61.33
Enterprise.nl	Passenger car	Opel Corsa	140.69
	Van	/	/
Europcar	Passenger car	/	/
	Van	/	/
Hertz	Passenger	Kia EV6	101.72
	Van	/	/
DIKS	Passenger car	Peugeot E2008 (CE)	70
	Van	Mercedes EVITO (VIAE)	165
Oscar	Passenger car	VW ID.3	59
	Van	Opel Vivaro-e	89

Table 27: Worst-case scenario for BAU rental costs

Rental company	Vehicle type	Vehicle name	Cost/day (€)
SIXT	Passenger car	BMW X5	179.48
	Van	Mercedes-Benz vito	64.33
Enterprise .nl	Passenger car	Volvo V90 STW	587.62

Rental company	Vehicle type	Vehicle name	Cost/day (€)
	Van	/	/
Europcar	Passenger car	Nissan Qashqai 1.3	91.98
	Van	VW T6 minibus long 2.0 TDI	185.02
Hertz	Passenger car	(L6) Volvo XC90	292.45
	Van	/	/
DIKS	Passenger	Peugeot 5008	120.00
	Van	Mercedes V-Class	225.00
Oscar	Passenger	Skoda Karoq	59.00
	Van	VW Multivan	120.00

Table 28: Worst-case scenario for MM rental costs

Rental company	Vehicle type	Vehicle name	Cost/day (€)
SIXT	Passenger car	BMW iX	140.02
	Van	Mercedes Benz e-vito	64.33
Enterprise.nl	Passenger car	Audi Q4 e-tron	186.00
	Van	/	/
Europcar	Passenger car	/	/
	Van	/	/
Hertz	Passenger car	(T1) Tesla Model 3 LR	114.04
	Van	/	/
DIKS	Passenger car	KIA Nero EV (SUVE)	85.00
	Van	Mercedes EQV	225.00

Rental company	Vehicle type	Vehicle name	Cost/day (€)
Oscar	Passenger car	Audi e-tron	99.00
	Van	Opel Vivaro-e	89.00

An average cost was taken from both the ICE and electric vehicles for each price range and multiplied across the number of cars rented for this production, 8 passenger cars and 8 vans for a total of 126 shooting days. This cost data is represented in Table 29 and 30 This total cost per price range was then tested within the sensitivity analysis.

Table 29: Average total cost over shooting period for diesel/petrol vehicles.

Price range	Vehicle type	Average cost per day (€)	Total rental price/vehicle type (€)	Total per price range (€)
Best (low)	Passenger car	56.15	56599.2	108843.84
	Van	51.83	52244.64	
Worst (high)	Passenger car	221.755	223529.04	373305.24
	Van	148.5875	149776.2	

Table 30: Average total cost over shooting period for electric vehicles

Price range	Vehicle type	Average cost per day (€)	Total rental price/vehicle type (€)	Total per price range (€)
Best (low)	Passenger car	86.548	87240.384	193191.264
	Van	105.11	105950.88	
Worst (high)	Passenger car	124.812	125810.496	252929.376
	Van	126.11	127118.88	

3.7.1.2 Best- and worst-case scenarios for consumption parameter

Consumption rates of both diesel/petrol and electric vehicles are also analyzed in a best-worst case scenario where the best is the lowest consumption rate and the worst case is the highest consumption rate. These values were taken for each of the identified vehicles in the previous section. Data for consumption rates related to the ICE vehicles is found in Table 31, while data for electric vehicles is found in Table 32.

Table 31: Consumption rate (L/100km) for diesel/petrol vehicles.

Vehicle type	**Vehicle name**	**Best case: low consumption rate (L/100km)**	**Worst case: consumption rate (L/100km)**	**Source**
Passenger car	Opel Mokka	4.4	5.2	Ultimatespecs, 2016
	BMW X5	8.8	9.5	BMW, 2023
	Opel Corsa	4.8	4.8	Opel, 2023
	Volvo V90 STW	4.5	4.9	Auto, 2016
	Renault Clio 1.0	3.7	5.6	Auto Data, 2019
	Nissan Qashqai 1.3	4.9	6.9	Car.info, 2022
	Opel Corsa	4.8	4.8	Opel, 2023
	(L6) Volvo XC90	11.2	13.5	Auto, 2020
	Nissan Micra [B]	5.9	6.5	Carsguide, 2015
	Peugeot 5008	5	6	Car emissions, 2013
	Hyundai i10	5.3	5.3	Car emissions, 2014
	Skoda Karoq	4.5	5.3	Auto, 2017
Van	Mercedes-Benz vito	6.1	7.1	Crasguide, 2023
	Volvo V90 STW	2	7.4	Auto, 2016
	VW T6 minibus long 2.0 TDI	7.8	8.3	Car.info, 2019
	Mercedes Sprinter	7.5	9.4	Mercedes-Benz, 2019
	Mercedes V-Class	9.3	9.3	Mercedes-Benz, 2017
	VW Multivan	6.5	7.7	Carsguide, 2020

Table 32: Consumption rate (wh/km) for electric vehicles.

Vehicle type	**Vehicle name**	**Best case: Low consumption rate (wh/km)**	**Worst case: High consumption rate (wh/km)**	**Source**
Passenger car	Kia e-niro	112	183	EV database, 2022
	BMW iX	138	273	EV database, 2021
	Opel Corsa	105	226	EV database, 2021b
	Audi Q4 e-tron	129	264	EV database, 2021c
	Kia EV6	124	255	EV database, 2021d
	Peogeot E2008 (CE)	117	250	EV database, 2020
	KIA Nero EV (SUVE)	112	236	EV database, 2022b
	VW ID.3	112	232	EV database, 2023
	(T1) Tesla Model 3 LR	117	142	EV database 2021
Van	Mercedes Benz e-vito	198	409	EV database, 2020b
	Mercedes EVITO (VIAE)	198	409	EV database, 2020b
	Mercedes EQV	200	409	EV database, 2020c
	Opel Vivaro-e	172	368	EV database, 2020d

Different consumption rates will affect the fuel cost and charging cost for the baseline and MM respectively. The lowest and highest consumption rates were taken as an average for the baseline and MM for each vehicle type. This is shown in Table 33 and Table 34 for the baseline and MM respectively. The corresponding effects on fuel cost are exhibited in Table 35 and 36, and on charging cost in Table 37 and 38. Charging costs were calculated using the same calculator in the main analysis (European Commission, 2022).

Table 33: Average highest and lowest fuel consumption rates (L/100km) for the BAU in reference to their vehicle type.

	Average	
Vehicle type	Best case: Low consumption rate (L/100km)	Worst case: High consumption rate (L/100km)
Passenger car	5.65	6.52
Van	6.53	8.2

Table 34: Average highest and lowest energy consumption rates (kWh/100km) for the MM in reference to their vehicle type.

	Average	
Vehicle type	Best case: Low consumption rate (kWh/100km)	Worst case: High consumption rate (kWh/100km)
Passenger car	11.84	22.9
Van	19.2	39.87

Table 35: Best-case fuel cost for average low consumption rate

Vehicle type		**Consumption (L/100km)**	**Predicted distance travelled (km)**	**Total fuel/vehicle (L)**	**Amount spent on fuel (€)**
Van		6.53	192000	12537.6	22680.52
Passenger car	**PA car**	5.65	9600	542.4	1144.46
	Other	5.65	160000	9040	19074.40
				Total (€)	**42899.38**

Table 36: Worst case fuel cost for average high consumption rate

Vehicle type		**Consumption (L/100km)**	**Predicted distance travelled (km)**	**Total fuel/vehicle (L)**	**Amount spent on fuel (€)**
Van		8.2	192000	15744	28480.90
Passenger car	**PA car**	6.52	9600	625.92	1320.69
	Other	6.52	160000	10432	22011.52
				Total (€)	**51813.11**

Table 37: Best case charging costs for average low consumption rate (kWh/100km)

Vehicle type	Distance (km)	Consumption rate (kwh/100km)	Recharging cost per 10000km (€/10000km)	Total km/10000km[9]	Recharging cost (€)[10]
Van	168,000	19	855	16.8	14364.00
Passenger car (other car)	9,600	12	/	/	513.00
Passenger car (PA car)	160,000	12	540	16	8,640.00
				Total (€)	**23517.00**

Table 38: Worst case charging costs for average high consumption rate (kWh/100km)

Vehicle type		Distance (km)	Consumption rate (kwh/100km)	Recharging cost per 10000km (€/10000km)	Total km/10000km	Recharging cost (€)
Van		168,000	35	1575	16.8	26,460.00
Passenger car	Other car	9,600	24	/	/	1,037.00
	PA car	160,000	24	1080	16	17,280.00
					Total (€)	**44777.00**

3.7.1.3 Best- and worst-case scenario for Public vs. Private charging parameter

The effect of using publicly available charging facilities and private charging facilities on the charging cost price for the electric vehicles was demonstrated in this section. The same calculator was used, with the same predicted distances and the same consumption rates which were used in the main analysis (European Commission, 2022). A best- and worst-case scenario was also used in this section, where the worst-case scenario was 100% private charging compared to the best-case scenario which was 100% public charging. Table 39 and 40 show the cost values specific to each.

Table 39: Best-case scenario using 100% public charging facilities and its effect on the total charging cost

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[9] This takes the total distance travelled by the vehicle type divided by 10000km because the online calculator is limited until 10000km

[10] Calculation: total km/10000km*recharging cost per 10000km

Vehicle type		**Distance (km)**	**Consumption rate (kwh/100km)**	**Recharging cost per 10000km (€/10000km)**	**Total km/10000 km**	**Recharging cost (€)**
Van		168,000	29	1683	16.8	28274.40
Passenger car	Other car	9,600	16.2	/	/	891.00
	PA car	160,000	16.2	928	16	14848.00
					Total (€)	**44013.40**

Table 40: Best-case scenario using 100% private charging facilities and its effect on the total charging cost

Vehicle type		**Distance (km)**	**Consumption rate (kwh/100km)**	**Recharging cost per 10000km (€/10000km)**	**Total km/10000km**	**Recharging cost (€)**
Van		168,000	29	928	16.8	15590.40
Passenger car	Other car	9,600	16.2	/	/	492.00
	PA car	160,000	16.2	512	16	8192.00
					Total (€)	**24274.40**

3.7.2 Measure category 2: OsP

3.7.2.1 BAU and Low carbon fuel MM

The main analysis used a fuel consumption average provided by the generator manager for both the BAU and the low carbon fuel MM. This amounted to 30L per shooting day. This value is expected to fluctuate day to day and during other productions dependent on the number and type of lights, camera equipment, special effects, set design, climate conditions, location, time of day, production schedule, crew size, and the adoption of energy-efficient technologies (Victory, 2015). Variability in fuel consumption by generators may influence the environmental impact in terms of emissions and the associated costs of fuel procurement (Victory, 2015).

To address the data range for the fuel consumption the generator manager was asked to provide the lowest and highest amount of fuel consumed in a shooting day on Pupkin’s tentpole TV series so far (Het Licht representative, personal communication, August 7, 2023). These data points were used in a best- and worst-case scenario analysis to assess the effect on fuel cost and associated emissions within the contexts of the BAU and the low carbon fuel MM.

The calculator states that it uses EFs specific to the country that the production is based in however, it does not specify its source (Albert, 2022). To ensure accuracy within the Netherlands, the EF of diesel, petrol and HVO100 fuel were outsourced from national statistics and tested in the sensitivity analysis.

3.7.2.1.1 Best- and worst-case scenario for fuel consumption's effect on costs and emissions

The best-case scenario refers to the costs and emissions associated with a lower draw, which was a total of 17L of fuel, while the worst-case scenario would be the higher draw, 40L of fuel (Het Licht representative, personal communication, August 7, 2023). The same cost of diesel and HVO100 per liter were used as done in the main analysis (Centraal Bureau, 2023; Full Tank, 2023). Data relating to the best- and worst-case scenario for the BAU is seen in Table 41 and for the low carbon fuel MM, in table 42.

Table 41: BAU costs and emissions in best- and worst-case scenario

Best-case (17 liters)			**Worst-case (40 liters)**		
Total diesel used (L)[11]	Emissions (t CO_2)[12]	Cost (€/L)	Total diesel used (L)	Emissions (tCO_2)	Cost (€/L)
986	3.12	1783.674	2320	7.35	4196.88

Table 42: Low carbon fuel MM costs and emissions in best- and worst-case scenario

Best-case (17 liters)			**Worst-case (40 liters)**		
Total diesel used (L)	Emissions (tCO_2)	Costs (€/L)	Total diesel used (L)	Emissions (tCO_2)	Costs (€/L)
986	0.38	2055.9086	2320	0.99	4837.43

3.7.2.1.2 Comparative analysis of EFs specific to the Netherlands

Albert uses emission factors outsourced form the European investment bank (EIB), 2022. The emission factors consider well-to-tank (WTT) emissions which cover all the associated emissions with the production of a fuel, transport, distribution, marketing and delivery to the fuel's vessel (Albert, 2022). This factor is 2.7kgCO_2eq/L of gas/diesel oil. This was checked against the emission factor for gas/diesel oil published by the GHG protocol (2017) which is also 2.7kgCO_2eq/L. To ensure accuracy within the Netherlands the national emission factor for diesel was outsourced from the Netherlands Enterprise Agency (NEA) (2022) which exhibited an

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[11] Calculation: amount of fuel*58 shooting days

[12] Emissions were calculated using Albert Calculator as done in main analysis

emission factor of 72.5kgCO_2eq /GJ. This did not specify whether WTT or well-to-wake (WTW) emissions were considered but was used to check against the emission factors from EIB (2022) and the GHG protocol (2017). The calculations are as follows:

The standard energy content of diesel is approximately 38.6 gigajoules (GJ) per liter.

CO_2 emissions/liter of diesel:

- Energy content of diesel = 43.2 MJ/kg (NEA, 2022)

Convert energy content to GJ/L [since 1 GJ = 1000 MJ and 1 liter of diesel weighs approximately 0.835 kg (Statistics Netherlands, 2024)]:

- Energy content of diesel = 43.2 MJ/kg * 0.835 kg/L = 36.072 MJ/L
- CO_2 emissions per liter of diesel = (72.5 kgCO_2eq/GJ) * (0.036072 GJ/L) = 2.6 kgCO_2eq/L

Since there was only 0.1 of a difference between the official EF used in the Netherlands compared to that of Albert, this factor was not considered in the sensitivity analysis.

3.7.2.3 Battery charging emissions

The main analysis assumes that all charging stations are powered by grey electricity. This is subject to change during shooting depending on the closest charging station to the shooting location. Some charging stations in the Netherlands are powered by renewable energy and will not produce any emissions when used to charge the battery (NEA, 2019). The sensitivity analysis takes note of this and adjusts the emissions according to the following charging ratios split across the 57 days of shooting.

Table 43: Charging ratios for sensitivity analysis

Green electricity		**Grey electricity**		**Emissions (tCO_2)**[13]
(%)	**No. of days**	**(%)**	**No. of days**	
100	57	0	0	0
80	45.6	20	11.4	0.65
60	34.2	40	22.8	1.30
40	22.8	60	34.2	1.96
20	11.4	80	45.6	2.61

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[13] Emissions were calculated using (energy consumption*grey electricity EF)*No. of days in grey electricity ratio $(x)/1000$ = (109.38*0.523)* $x/1000$t CO_2eq

3.7.3 Measure category 3: Office Power

A sensitivity analysis was not performed for office power because cost values were retrieved from several energy production companies, compensating for the variance across the Netherlands.

3.7.4 Measure category 4: Accommodation

A best-case and worst-case scenario analysis was used to investigate uncertain parameters in Measure category 4. The main study employed an average value as a representative metric to quantify the number of occupied rooms in different types of hotels. Based on occupancy data obtained from Pupkin's production assistants, the accommodation data was modified to assess the sensitivity of the parameter. This value has significant influence on the cost parameters, so the lowest occupancy value was used in the best case, while the highest available figure was used in the worst-case scenario. Modified occupancy does not affect the emissions in this case because emission savings are 100% due to the Albert calculator assuming 0tCO_2 from certified accommodation. The assumption from the calculator is tested separately for the MM. As such, the sensitivity analysis carefully examined the implications of changes in hotel occupancy on cost dynamics as well as the effect of testing the 100% emission savings.

3.7.4.1 Best- and worst- case scenario for cost variation

The best-case scenario represents an occupancy of 25 individuals while the worst-case scenario represents an occupancy of 65 individuals. As done in the main analysis, 2 people per room are accounted for in each hotel accommodation. The best- and worst case for the BAU are exhibited Table 44 and table 45. While for the MM, in table 46 and Table 47.

Table 44: BAU best-case scenario: low occupancy

Block	**Location**	**Hotel names**	**Cost per night**	**Number of rooms**[14]	**Number of nights**	**Cost (€)**
1	Groningen	Mercure Hotel Groningen	141	12.5	20	35250.00
2	Amsterdam	Olympic hotel	143	12.5	21	37537.50
3	Groningen	Mercure Hotel Groningen	141	12.5	31	54637.50
					Total cost (€)	**127425.00**

Table 45: BAU worst-case scenario: cost variation with high occupancy

Block	**Location**	**Hotel names**	**Cost per night**	**Number of rooms**[15]	**Number of nights**	**Cost (€)**
1	Groningen	Mercure Hotel Groningen	141	32.5	20	91650.00
2	Amsterdam	Olympic hotel	143	32.5	21	97597.50
3	Groningen	Mercure Hotel Groningen	141	32.5	31	142057.50
					Total cost (€)	**331305.00**

Table 46: MM best-case scenario: cost variation low occupancy

Block	**Area**	**Hotel names**	**Cost per night**	**Number of rooms**	**Number of nights**	**Total cost (€)**
1	Amsterdam	Conscious hotel	224	12.5	21	58800.00
2	Groningen	Flonk hotel	126	12.5	20	31500.00
3	Groningen	Flonk hotel	126	12.5	31	48825.00
					Total cost (€)	**139125.00**

Table 47: MM worst-case scenario: cost variation high occupancy

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[14] Calculation: 25 individuals/ 2 individuals per room

[15] Calculation: 65 individuals/2 individuals per room

Block	**Area**	**Hotel names**	**Cost per night**	**Number of rooms**	**Number of nights**	**Cost (€)**
1	Amsterdam	Conscious hotel	224	32.5	21	152880.00
2	Groningen	Flonk hotel	126	32.5	20	81900.00
3	Groningen	Flonk hotel	126	32.5	31	126945.00
					Total cost (€)	**361725.00**

3.7.4.2 Emission variation: MM sensitivity analysis

This parameter was tested because the Albert Calculator assumes 0tCO_2 emissions are produced by an accommodation which is sustainably certified because it believes that the company is using 100% renewable electricity (Albert, 2022). The main analysis uses accommodations which are certified under Green Key certification. This certification upholds a multidisciplinary idea of sustainability within the hospitality sector across various impact areas, one of which being energy use within the establishment (Green Key, 2023). However, energy scoring is based on energy conservation policies, energy efficient lighting, sustainable heating ventilation and air conditioning (HVAC) systems, energy monitoring and reporting, staff training and the extent the hotel incorporates renewable energy sources (Green Key, 2023). Although it reflects a high standard of multidisciplinary sustainability, even a gold-level hotel does not mandate 100% renewable electricity. Therefore, even though the Albert Calculator assumes 0tCO_2eq for certified accommodations the reality is that they are likely to emit more.

Accor hospitality under the Green Key certification set a target to reduce their emissions by 46% compared to those before being certified (Green Key, 2021). As a more representative data point the sensitivity analysis takes the emission produced in the BAU using the average occupancy data (40 individuals) and reduces them by 46%. This data is represented in table 48.

Table 48: Emission data under 46% emission reduction target submitted by Accor hospitality.

Shooting block	**Number of nights**	**Original CO_2 emissions (tCO_2)**	**46% reduction in emissions**
1	20	5.41	2.9214
2	21	5.68	3.0672
3	31	8.38	4.5252
		Total emissions (tCO_2)	**10.5138**

3.7.5 Catering

A sensitivity analysis was omitted for Measure category 5: Catering, as cost data pertaining to various meal types were sourced from multiple catering companies in the Netherlands. This approach compensates for the variance in costs across different companies on a national scale.

4. Results

4.1 Identification of relevant MMs

4.1.1 MM grouping

37 MMs were identified from online credible sources (Lopera-Marmol & Jimenz-Morales, 2021; Ecoprod, 2023; European Commission, 2021; Lupu et al. 2023; Rudenauer et al., 2021; Albert 2022; Albert 2021; Green Production Guide (GPG), 2023; Callebaut, 2022; Mohebi 2022; KZN Film Commission 2020; Victory, 2015; Dsouza, 2022; Patten, 2020). The MMs were grouped based in the Measure category they corresponded to. The comprehensive list is observed in table 49.

Table 49: Categorization of identified MMs based on impact category.

Measure category	**MM**	**Source**[16]
Transport of Crew	Public transport from accommodation to set	(1 ;2 ;3 ;4 ;5 ;6)
Transport of Crew	Bike transport from accommodation to set.	(4)
Transport of Crew	Carpool from accommodation to set.	(1 ;2 ;3 ;4 ;5 ;6)
Transport of Crew	Transport using efficient vehicles (LPG, CNG, bio-CNG, E-vehicles, hybrid cars).	(9 ;10 ;11 ;4)
Transport of Materials	Optimize equipment loading and delivery - evaluate options for base-camp parking that is closest to set to reduce fuel emissions.	(12 ;5 ;6 ;4 ;2 ;1)
Transport of Materials	Use of large capacity production vehicles for material transport (hybrid, E-trucks, CNG, LNG, Diesel Euro 6).	(11 ;10 ;9 ;1)
Transport of Materials	Use of efficient on-set vehicles (wardrobes, makeup vans, breakrooms, catering vans, mobile toilets).	(11 ;10; 9; 1)
Transport of Materials	No idling policy for vehicles on set.	(11 ; 10; 9; 1)
On-set power	Public connection to the grid wherever possible.	(1; 3; 4)
On-set power	Battery-powered generators	(11 ;4)
On-set power	Solar power sets (LED/solar generator supplies)	(13 ;9 ;10 ;4)
On-set power	Hydrogen generators	(9; 4)
On-set power	If traditional generators are used - alternative fuels to diesel will be used (low carbon fuels, Cynar plc, Biopetroleo)	(13; 12; 4; 3; 10)
On-set power	Hybrid generator technologies.	(1; 9; 11; 5; 5; 14)

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[16] The key for the citations is found below Table 44

Measure category	**MM**	**Source**[16]
Office energy	Switch to sustainable electricity provider.	(9; 11, 2021; 7)
Office energy	LED lightbulbs.	(1; 15; 9;11; 3)
Office energy	Heat offices with natural gas or biogas.	(9)
Office energy	Heat offices with solar heating.	(9)
Office energy	Metered/automated systems that shutdown lighting/heating and cooling.	(9)
Office energy	Replace desktop computers with notebooks or minicomputers.	(9)
Office energy	Invest in structural changes of offices to insulate/cool appropriately.	(9)
Office waste reduction/sorting	Create specific waste sorting system (eg. batteries, lights, plastics, paper, glass).	(15; 9; 10; 11; 7)
Office waste reduction/sorting	Paperless office strategy.	(5; 5)
Office waste reduction/sorting	If paper is used source recycled paper.	(9)
On-set waste reduction	Limit overconsumption of single use products (gaffer tape, grips, straps, ropes, plastic etc.).	(1; 3; 4)
On-set waste reduction	Avoid virgin material production - rent or reuse props, set design elements and costumes.	(15; 7; 3; 4; 12)
On-set waste reduction	Sustainable sourced materials where virgin materials are required.	(7)
On-set waste reduction	Paperless scripts unless requested.	(11; 3; 4; 5; 5)
On-set waste reduction	If requested print on recycled paper.	(9)
On-set waste sorting	Sort waste for recycling, reuse and landfill.	(15; 9; 11; 7; 3; 4)
On-set waste sorting	Schedule recycling pick ups with waste removal.	(4)
On-set waste sorting	Make a set design repertoire - items that can be stored and reused for other productions.	(15)
Accommodation	Find accommodation as close to the filming site as possible.	(1)
Accommodation	Find green certified accommodation.	(1; 3; 11)
Catering	Donate surplus food to local associations.	(1)
Catering	Chosen catering company should source food locally and ideally vegetarian/vegan - opt in meat option.	(9 ; 11)
Catering	Eliminate single use cutlery.	(4)

Source Key:

(1) Lopera-Marmol & Jimenz-Morales,2021; (2) Albert,2020; (3) Albert,2021; (4) GPG,2023; (5) Callebaut, 2022; (6) Mohebi,2022, (7) Albert, 2020; (8) Albert 2021; (9) European Commission, 2021; (10) Lupu et al., 2023; (11) Rudenauer et al., 2021; (12) KZN Film Commission, 2020; (13) Victory, 2015; (14) Volstack, 2023; (15) Ecoprod, 2023

4.1.2 Selection criteria

The 37 identified MMs were then passed through the selection criteria below:

1. MMs need to be applicable to carbon intensive activities within production phase. ‘Carbon intensive’ can be defined as contributing to more than 5% of production emissions (de Souza et al., 2018).
2. MMs must be applicable to context of the AV production.
3. MMs that are estimated to have a high abatement potential (>2%) should be chosen. (Moran et al., 2010).
4. MMs with low data availability must be excluded (GHG Protocol, 2013).
5. MM must be feasible to analyze within the time constraints of this project.

Table 45 exhibits the decisions made through the application of the selection criteria, leaving a total of 7 chosen MMs to build the MACC (see section 3, Figure 5). The chosen MMs are highlighted in green while those excluded from analysis are highlighted in red (see table 50).

Table 50: 37 identified MMs and the corresponding selection criteria

Measure category	**MM Title**	**Selected for MACC (⍰/X)**	**MM Selection Criteria**				
			1	**2**	**3**	**4**	**5**
Transport of crew	Public transport from accommodation to set	X	⍰	⍰	⍰	⍰	X
Transport of crew	Bike transport from accommodation to set	X	⍰	⍰	X	⍰	⍰
Transport of crew	Carpool from accommodation to set	X	⍰	⍰	⍰	X	X

Measure category	MM Title	Selected for MACC (⍰/X)	MM Selection Criteria				
			1	2	3	4	5
Transport of crew	Transport using efficient vehicles (LPG, CNG, bio-CNG, E-vehicles, hybrid cars)	⍰	⍰	⍰	⍰	⍰	⍰
Transport of materials	Optimize an efficient transport plan, eg. equipment loading and delivery - evaluate options for base-camp parking that is closest to set to reduce fuel emissions	X	⍰	⍰	⍰	X	X
Transport of materials	Use of large capacity production vehicles for material transport (hybrid, E-trucks, CNG, LNG, Diesel Euro 6)	X	⍰	⍰	⍰	X	⍰
Transport of materials	Use of efficient on-set vehicles (wardrobes, makeup vans, breakrooms, catering vans, mobile toilets)	X	⍰	⍰	⍰	X	⍰
Transport of materials	No idling policy for vehicles on set	X	⍰	⍰	⍰	X	⍰
On-set power	Public connection to the grid wherever possible	X	X	⍰	⍰	X	X
On-set power	Battery-powered generators	⍰	⍰	⍰	⍰	⍰	⍰
On-set power	Hybrid Solar power sets (LED/solar generator supplies)	⍰	⍰	⍰	⍰	⍰	⍰

Measure category	MM Title	Selected for MACC (⍰/X)	MM Selection Criteria				
			1	2	3	4	5
On-set power	Hydrogen generators	X	X	⍰	⍰	X	X
On-set power	If traditional generators are used - alternative fuels to diesel will be used (low carbon fuels, Cynar plc, Biopetroleo)	⍰	⍰	⍰	⍰	⍰	⍰
Office power	Switch to sustainable electricity provider	⍰	⍰	⍰	⍰	⍰	⍰
Office power	LED lightbulbs	X	⍰	⍰	⍰	X	X
Office power	Heat offices with natural gas or biogas	X	⍰	⍰	⍰	X	X
Office power	Heat offices with solar heating	X	X	⍰	⍰	X	X
Office power	Metered/automated systems that shutdown lighting/heating and cooling	X	⍰	⍰	⍰	X	X
Office power	Replace desktop computers with notebooks or minicomputers	X	⍰	⍰	⍰	X	X
Office power	Invest in structural changes of offices to insulate/cool appropriately	X	⍰	⍰	⍰	X	X

Measure category	MM Title	Selected for MACC (⍰/X)	MM Selection Criteria				
			1	2	3	4	5
Office waste	Create specific waste sorting system (eg. batteries, lights, plastics, paper, glass)	X	⍰	X	X	X	X
Office waste	Paperless office strategy	X	⍰	X	X	X	X
Office waste	If paper is used source recycled paper	X	⍰	X	X	⍰	X
On-set waste reduction	Limit overconsumption of single use products (gaffer tape, grips, straps, ropes, plastic etc.)	X	⍰	⍰	X	X	X
On-set waste reduction	Avoid virgin material production - rent or resue props, set design elements and costumes	X	⍰	⍰	X	X	X
On-set waste reduction	Sustainable sourced materials where virgin materials are required	X	⍰	⍰	X	X	X
On-set waste reduction	Paperless scripts unless requested	X	⍰	⍰	X	X	X
On-set waste reduction	If requested print on recycled paper	X	⍰	⍰	X	X	X
On-set waste sorting	Sort waste for recycling, reuse and landfill	X	⍰	X	X	X	X
On-set waste sorting	Schedule recycling pick ups with waste removal	X	⍰	X	⍰	⍰	⍰

Measure category	MM Title	Selected for MACC (⍰/X)	MM Selection Criteria				
			1	2	3	4	5
On-set waste sorting	Make a set design repertoire - items that can be stored and reused for other productions	X	⍰	X	⍰	X	X
Accommodation	Find accommodation as close to filming site as possible	X	⍰	⍰	⍰	⍰	X
Accommodation	Find green certified accommodation	⍰	⍰	⍰	⍰	⍰	⍰
Catering	Donate surplus food to local associations	X	⍰	X	X	X	X
Catering	Chosen catering company should source food locally and ideally vegetarian/vegan - opt in meat option	⍰	⍰	⍰	⍰	⍰	⍰
Catering	Eliminate single use cutlery	X	⍰	⍰	X	X	X

4.2 Measure categories in the context of Pupkin’s tentpole production“

This section describes each of the chosen measures in a qualitative manner, within the context of Pupkin’s tentpole TV series.

4.2.1 Measure category 1: Transport of Crew

Various departments (refer to Section 2, figure 4) and individuals are involved in supporting a TV series throughout the production period. The cast and crew need to be transported to and from set each shooting day, the frequency of travel is dependent on the department that the vehicle belongs to. In the case of this TV series, the amount of people that needed to be transported to and from set would vary according to the shooting day, ranging from 30-50 individuals. Pupkin rented enough vehicles to cover the transportation needs of the highest number of individuals on set throughout the entire production period (126 days). These vehicles were rented from DIKS rental company, which was used to obtain data for both the BAU and MM. Other Dutch production companies might rent vehicles from other rental companies offering different vehicles at a different cost; hence this will be accounted for in the sensitivity analysis. The vehicles rented for the production comprised 8 vans and 4 cars, which were distributed across all the departments. An additional 4 cars were also rented for the production assistants (PAs).

4.2.2 Measure category 2: On-set Power

AV productions require considerable energy to power equipment including lighting, cameras, computers, sound systems and mechanical equipment on set, this is usually supported by a generator. To ensure that the set remains supported an estimation on the power-draw from the generator is made and relayed to the generator rental company. For this production, the location manager calculated a non-constant energy requirement of 12kWh over a 10.25 hour shooting day (Location manager, personal communication, August 9, 2023).

4.2.3 Measure category 3: Office Power

Throughout the production period, Pupkin's offices remain in use to manage logistics within this production, additional ongoing productions and other daily activities. Gas and electricity are both used to generate heat and power in the office, respectively. Electricity streams can either originate from green or grey energy sources, the former being renewable and the latter non-renewable. This section focuses on comparing energy suppliers who provide green and grey electricity (European Commission, 2023; Rudenauer et al., 2021; Albert, 2020). Suppliers were chosen based on a comparative study carried out by WISE (2021).

4.2.4 Measure category 4: Accommodation

Due to the TV series being shot on multiple locations, various accommodations are required to accommodate the entire crew day-to-day. Section 3.4.2, figures 6,7,8 exhibit the various shooting locations throughout the different shooting blocks. Even though the shooting locations are fairly spread out, one hotel is booked for each block.

Shooting took place on 4 or 5 days throughout each week, but hotels were booked throughout the whole shooting period of each block. Additionally, the number of people in each hotel differed day-to-day by +/- 5-10 people but this study assumes an average of 40 residents in each hotel throughout all three blocks.

4.2.5 Measure category 5: Catering

Each shooting day spans over a period of around 10 hours. During this time the production team and cast are given one sufficient meal usually provided by a hired catering service throughout the three shooting blocks. This meal will be considered vegan or vegetarian throughout the whole shooting period. The catering service provider is usually the same throughout the whole shooting period.

4.3 Baseline scenario

4.3.1 Measure category 1: BAU Transport of Crew

The results for this scenario can be found in Table 51, this table presents all costs and emissions associated with the BAU for Measure category 1. Refer to Appendix B.1 for the calculations specific to the data points in Table 47.

Table 51: BAU calculation for Measure category 1

Costs (€)		**Emissions (tCO$_2$eq)**		
Total rental costs over shooting period	191,520	Mercedes Sprinter (Double Cabin)		55.78
Fuel & Operational Costs	49,535.43	Nissan Micra [B]	Other	3.41
			PA car	56.76
Total costs	**241055**	**Total emissions**		**115.95**

4.3.2 Measure category 2: BAU On-set Power

Results for the BAU calculation can be observed in Table 52, the calculations for each data point are illustrated in Appendix B.1.

Table 52: BAU calculation

Costs (€)			**Emissions (tCO_2eq)**	
Rental costs per day		250.00	Direct emissions from running generator	5.51
Rental costs over shooting period		31500.00	Emissions from transporting generator between locations	0.87
Rental costs over shooting period	Cost of diesel for generator	**3147.66**		
	Diesel for transporting generator between locations	**771.72**		
Total costs		**35419.37**	**Total emissions**	**6.38**

4.3.3 Measure category 3: BAU Office power

Results for this scenario are observed in Table 53, which depicts relevant data associated with the BAU for Office power.

Table 53: BAU calculation

Costs (€)		**Emissions (tCO_2eq)**	
Rental costs per month	420.69	Carbon emissions (tCO_2eq)	15.02
Rental costs over shooting period (4 months)	1682.76		
Fuel & Operational costs	0		
Total costs	**1682.76**	**Total emissions**	**15.02**

4.3.4 Measure category 4: BAU Accommodation

Table 54 depicts relevant data for BAU calculation, calculations per data point are elaborated on in Appendix B.1.

Table 54: BAU calculation of Measure category 5.

Costs (€)		**Emissions (tCO$_2$eq)**	
Costs over shooting period	164400.00	Carbon emissions	15.69
Fuel & Operational costs	**0**	**Total emissions**	**15.69**
Total costs	**164400.00**		

4.3.5 Measure category 5: BAU Catering

Table 55 shows data points and MM calculation for Measure category 4, Catering. Relevant calculations for each data point are elaborated on in Appendix B.1.

Table 55: BAU calculation for Measure category 5.

Costs (€)		**Emissions (tCO$_2$eq)**	
Costs over shooting period	13252.84	Carbon emissions	10.96
Fuel & Operational costs	0	**Total emissions**	**10.96**
Total costs	**13252.84**		

4.4 MMs

4.4.1 Measure category 1: MM Transport of Crew

The results for this scenario are exhibited in table 56, where all associated costs and emissions with the MM are detailed. The table also includes emission savings and specific costs of the MM compared to Measure category 1: BAU. Refer to Appendix B.2 for calculations specific to the data points in table 56.

Table 56: MM calculation

Costs (€)		**Emissions (tCO$_2$eq)**		
Total rental costs over shooting period	200970	Mercedes Sprinter (Double Cabin)		12.85
Charging costs	43421.40	Nissan Micra [B]	Other	11.41
			PA car	0.68
Total costs	**244391.40**	Total emissions		24.94
		Emission savings (%)		78.50
		Specific costs		**42.50**

4.4.1.1 Measure category 2: Low-carbon fuel

Table 57 depicts relevant data points for MM calculation, also including the emission reduction potential as well as the specific costs of the MM compared to the BAU.

Table 57: MM calculation

Costs (€)			**Emissions (tCO_2eq)**	
Rental costs per day		250	Emissions from generator use	0.67
Rental costs over shooting period		31500	Emissions from transporting generator between locations	0.87
Fuel & Operational costs	Total cost of HVO100 fuel	3628.07	Total emissions	1.54
	Diesel for transporting between locations	771.72		
Total costs		**35899.79**	Specific Costs	6.7
			Specific costs	**42.50**

4.4.1.2 Measure category 2: MM OsP – Hybrid generator

Table 58 depicts relevant data points for MM calculation, also including the emission reduction potential as well as the specific costs of the MM compared to the BAU. The calculations specific to the data points in table 84 are illustrated in Appendix B.2.

Table 58: MM calculation

Costs (€)			**Emissions (tCO_2eq)**	
Rental costs per day		74.31	Emissions from hybrid generator	1.32
Rental costs over shooting period		9,363.60	Emissions from transporting generator between locations	0.87
Fuel & Operational costs	Transportation costs from and to rental company	377.64		
	Diesel for transporting between locations	771.72	Total emissions	2.19
Total costs		**10512.96**	Emission savings (%)	60.26
			Specific Costs	**-119**

4.4.1.3 Measure category 2: MM On-set Power – Battery powered generator

Table 59 depicts relevant data points for MM calculation, also including the emission reduction potential as well as the specific costs of the MM compared to the BAU. Calculations for data points in table 59 are exhibited in Appendix B.2

Table 59: MM calculation

Costs (€)			**Emissions (tCO_2eq)**	
Rental costs per day		136.56	Emissions from battery	3.26
Rental costs over shooting period		17207.10	Emissions from transporting generator between locations	0.87
Fuel & Operational costs	Transportation costs from and to rental company	400		
	Diesel for transporting battery between locations	771.72		
	Charging costs	2961.46	Total emissions	4.13
Total costs		**21340.28**	Emission savings (%)	35.16
			Specific Costs	**-400.37**

4.4.3 Measure category 3: MM Office power

Table 60 depicts relevant data points for MM calculation, also including the emission reduction potential as well as the specific costs of the MM compared to the BAU. Calculations per data point are shown in Appendix B.2

Table 60: MM Office power calculation.

Costs (€)		**Emissions (tCO_2eq)**	
Rental costs per month	393.35	Carbon emissions	0
Rental costs over shooting period (4 months)	1573.39		
Fuel & Operational costs	0		
Total costs	**1573.39**	Total emissions	0
		Emission savings (%)	100
		Specific Costs	**-1.09**

4.4.4 Measure category 4: MM Accommodation

Table 61 shows data points and MM calculation for Measure category 4, Accommodation.

Relevant calculations for each data point are elaborated on in Appendix B.2.

Table 61: MM calculation for Measure category 5.

Costs (€)		**Emissions (tCO_2eq)**	
Costs over shooting period	187320.00	Carbon emissions	0
Fuel & Operational costs	0	Total emissions	0
Total costs	**187320.00**		
		Emission savings (%)	100
		Specific Costs	**229.2**

4.4.5 Measure category 5: MM Catering

Table 62 shows data points and MM calculation for Measure category 5, Catering. Relevant calculations for each data point are elaborated on in Appendix B.2.

Table 62: MM calculation for Measure category 5.

Costs (€)		**Emissions (tCO_2eq)**	
Costs over shooting period	13,682.68	Carbon emissions	1.76
Fuel & Operational costs	0	Total emissions	1.76
Total costs	**13682.68**		
		Emission savings (%)	83.94
		Specific Costs	**5.12**

4.5 Build MACC

Comparisons between the CO_2 reduction potential and the specific costs the cost reduction potential are seen in table 63. The differences between the emissions and costs for each measure category are shown in table 64 and are the values used to build the MACC (Figure 10)

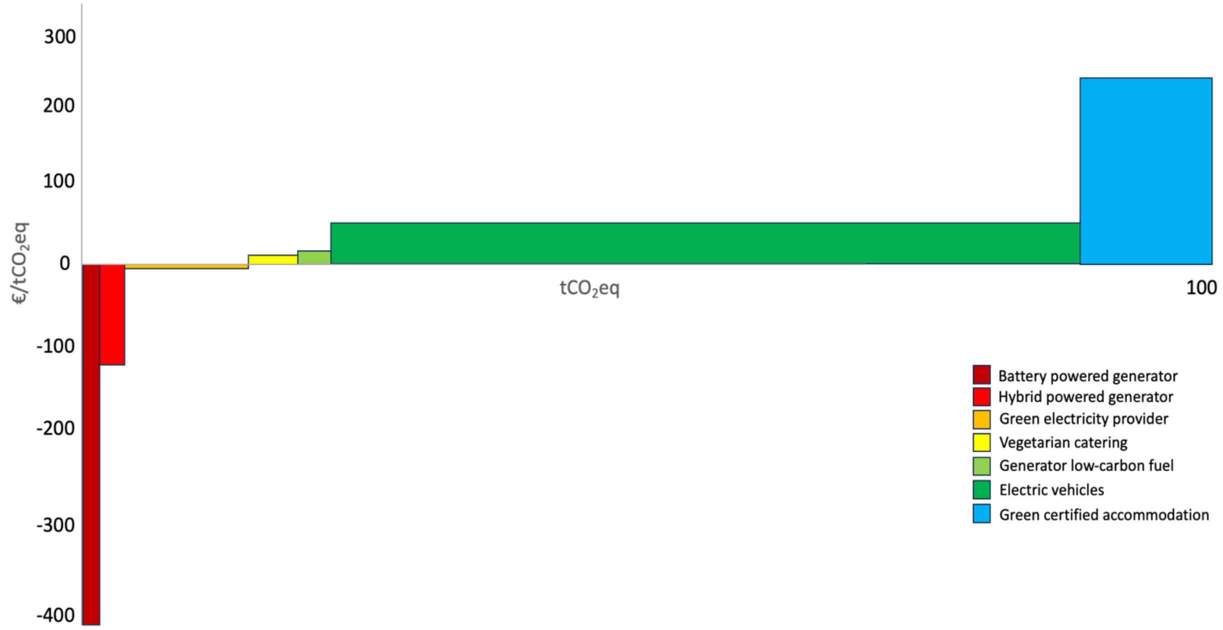
Table 63: Emission differences between MMs and BAU

		CO_2 production (tCO_2eq)	
Measure category	**MMs**	**MM**	**BAU**
Transport of Crew	Electric vehicles	24.94	115.95
On-set Power	Generator with low-carbon fuel	1.54	6.38
	Hybrid generator	2.19	
	Battery powered generator	4.13	
Office Power (electricity)	Green electricity provider	0	15.02
Accommodation	Green-key certified	0	15.69
Catering	Vegetarian catering	1.76	10.96
	Total	34.56	164

Table 64: MACC results for each Measure category

Measure category	**MMs**	**CO_2 reduction potential (negative) (tCO_2eq)**	**Specific costs (€/tCO_2eq)**
Transport of Crew	Electric vehicles	91.01	42.50
On-set Power	Generator with low-carbon fuel	3.97	6.70
	Hybrid generator	3.32	-119
	Battery powered generator	2.24	-400.37
Office Power (electricity)	Green electricity provider	15.02	-1.09
Accommodation	Green-key certified	15.69	229.2
Catering	Vegetarian catering	5.84	5.12

Figure 10: MACC using specific costs from all MMs in each Measure category



4.6 Sensitivity analysis

A sensitivity analysis was performed for measure category 1, 2 (low carbon fuel), 3 and 4. Each section addresses the change in specific costs according to the best- and worst-case scenarios which are compared against the "original specific costs" that represent the result in each measure category. These data are shown in all tables across the sensitivity analysis for reference purposes. The overview of all original specific costs can be observed in table 65.

Table 65: Overview of original specific costs across the measure categories

Measure category	MMs	Original specific costs
Transport of Crew	Electric vehicles	42.50
On-set Power	Generator with low-carbon fuel	6.70
	Hybrid generator	-119
	Battery powered generator	-400.37
Office Power (electricity)	Green electricity provider	-1.09
Accommodation	Green-key certified	229.2
Catering	Vegetarian catering	5.12

4.6.1 Measure category 1: Transport cast/crew

Results were separated across three sub-sections, specifically addressing the best- and worst-case scenarios for the rental cost parameter, consumption parameter, and the Public vs. Private charging parameter. Comprehensive details pertaining to each sub-section are exhibited below. 4.6.1.1 Best-and worst-case scenario for rental cost parameter

Best-case scenario analysis is exhibited in table 66, while the worst-case scenario is shown in Table 67.

Table 66: Best-case scenario for rental cost parameter

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	108843.80	Rental costs over shooting period (€)	193191.26
Fuel & Operational costs (€)	49535.43	Charging costs (€)	43421.40
Total costs (€)	158379.23	Total costs (€)	236612.66
Carbon emissions (tCO_2eq)	115.95	Carbon emissions (tCO_2eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**996.72**

Table 67: Worst-case scenario for rental cost parameter

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	373305.24	Rental costs over shooting period (€)	252929.38
Fuel & Operational costs (€)	49535.43	Charging costs (€)	43421.40
Total costs (€)	422840.67	Total costs (€)	296350.78
Carbon emissions (tCO_2eq)	115.95	Carbon emissions (tCO_2eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**-1611.53**

4.6.1.2 Best- and worst-case scenario for diesel/petrol vehicle consumption rate

Best-case scenario analysis is exhibited in table 68, while the worst-case scenario is shown in Table 69.

Table 68: Best-case scenario for consumption rate parameter

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	191520	Rental costs over shooting period (€)	200970
Fuel & Operational costs (€)	42899.38	Charging costs (€)	23517
Total costs (€)	234419.38	Total costs (€)	224487
Carbon emissions (tCO_2eq)	115.95	Carbon emissions (tCO_2eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**-126.54**

Table 69: Worst-case scenario for consumption rate parameter

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	191520	Rental costs over shooting period (€)	200970
Fuel & Operational costs (€)	51813.11	Charging costs (€)	44777
Total costs (€)	243333.11	Total costs (€)	245747
Carbon emissions (tCO_2eq)	115.95	Carbon emissions (tCO_2eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**30.75**

4.6.1.3 Best- and worst-case scenario for electric vehicle consumption rate

Best-case scenario analysis is exhibited in table 70, while the worst-case scenario is shown in Table 71.

Table 70: Best-case scenario for public charging stations

Data for BAU		Data for MM	
Rental costs over shooting period (€)	191520	Rental costs over shooting period (€)	200970
Fuel & Operational costs (€)	49535.43	Charging costs (€)	44013.4
Total costs (€)	241055.43	Total costs (€)	244983.4
Carbon emissions (tCO$_2$eq)	115.95	Carbon emissions (tCO$_2$eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**50**

Table 71: Worst-case scenario for private charging stations

Data for BAU		Data for MM	
Rental costs over shooting period (€)	191520	Rental costs over shooting period (€)	200970
Fuel & Operational costs (€)	49535.43	Charging costs (€)	24272.4
Total costs (€)	241055.43	Total costs (€)	225242.4
Carbon emissions (tCO$_2$eq)	115.95	Carbon emissions (tCO$_2$eq)	24.94
		Emission savings (%)	78.49
Original specific costs	**42.50**	**Specific costs**	**-201**

4.6.2 Measure category 2: On-set power, low carbon fuel

4.6.2.1 Best- and worst-case scenario for fuel consumption's effect on costs and emissions

Best-case scenario for fuel consumption's effects on costs and emissions is observed in table 72 and the worst-case scenario in Table 73.

Table 72: Best-case scenario for fuel consumption effect on cost and emissions

Data for BAU			**Data for MM**		
Rental Costs per day		250.00	Rental Costs per day		250.00
Rental costs over shooting period (€)		31500.00	Rental costs over shooting period (€)		31500.00
Fuel & Operational costs (€)	Cost of diesel for generator (€)	1783.67	Fuel & Operational costs (€)	Cost of diesel for generator (€)	2055.91
	Costs for transporting generator between shooting locations (€)	771.72		Costs for transporting generator between shooting locations (€)	771.72
Total costs (€)		34055.39	Total costs (€)		34327.63
Carbon emissions (tCO$_2$eq) for running generator		3.12	Carbon emissions (tCO$_2$eq) for running generator		0.38
Carbon emissions for transporting generator (tCO$_2$eq)		0.87	Carbon emissions for transporting generator (tCO$_2$eq)		0.87
Total emissions (tCO$_2$eq)		3.99	Total emissions (tCO$_2$eq)		1.25
			Emission savings		68.67
Original specific costs		**6.70**	**Specific costs**		**3.96**

Table 73: Worst-case scenario for fuel consumption effect on cost and emissions

Data for BAU			**Data for MM**		
Rental costs per day (€)		250.00	Rental costs per day (€)		250.00
Rental costs over shooting period (€)		31500.00	Rental costs over shooting period (€)		31500.00
Fuel & Operational costs (€)	Cost of diesel for generator (€)	4196.88	Fuel & Operational costs (€)	Cost of diesel for generator (€)	4837.43
	Costs for transporting generator between shooting locations (€)	771.72		Costs for transporting generator between shooting locations (€)	771.72
Total costs (€)		36468.6	Total costs (€)		37109.15
Direct emissions from generator (tCO_2eq)		7.35	Direct emissions from generator (tCO_2eq)		0.99
Carbon emissions for transporting generator (tCO_2eq)		0.87	Carbon emissions for transporting generator (tCO_2eq)		0.87
Total emissions (tCO_2eq)		8.22	Total emissions (tCO_2eq)		1.86
			Emission savings (%)		77.37
Original specific costs		**6.70**	**Specific costs**		**8.28**

4.6.2.2 Sensitivity analysis for Battery charging ratios (green electricity: grey electricity)

Specific costs were calculated according to the different ratios of green: grey power sources. The comparison between specific costs in the sensitivity analysis and the original calculation can be seen in table 74.

Table 74: Specific cost results against ratios of green:grey power sources

Ratio green: grey	**Emissions (tCO_2)**	**Emission savings (%)**	**Specific costs**	**Original specific costs**
100:0	0	100	-163.06	-400.37
80:20	0.652	89.76	-185.00	
60:40	1.304	79.53	-213.75	
40:60	1.957	69.28	-253.09	
20:80	2.609	59.04	-310.17	

4.6.3 Measure category 4: Accommodation

The analysis is divided into two sub-sections. The first focuses on the best and worst-case scenarios for cost data, specifically in relation to changes in occupancy data. The second sub-section assesses the sensitivity of emissions from the MM.

4.6.3.1 Best- and worst-case scenario for cost variation

Results for best-case scenario are shown in table 75, and in table 76 for the worst-case scenario.

Table 75: Best case scenario for cost variation

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	102750	Rental costs over shooting period (€)	117075
Total costs (€)	102750	Total costs (€)	117075
Carbon emissions (tCO$_2$eq)	15.69	Carbon emissions (tCO$_2$eq)	0
		Emission savings (%)	100
Original specific costs	**229.2**	**Specific costs**	**143**

Table 76: Worst case scenario for cost variation

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	267150	Rental costs over shooting period (€)	304395
Total costs (€)	267150	Total costs (€)	305395
Carbon emissions (tCO$_2$eq)	15.69	Carbon emissions (tCO$_2$eq)	0
		Emission savings (%)	100
Original specific costs	**229.2**	**Specific costs**	**372**

4.6.3.2 Emission variation for MM

Table 77 shows sensitivity analysis results for the emission variation in the MM.

Table 77: sensitivity analysis for MM emission variation

Data for BAU		**Data for MM**	
Rental costs over shooting period (€)	164400.00	Rental costs over shooting period (€)	187320
Total costs (€)	164400.00	Total costs (€)	187320
Carbon emissions (tCO_2eq)	15.69	Carbon emissions (tCO_2eq)	8.47
		Emission savings (%)	46
Original specific costs	**229.2**	**Specific costs**	**406**

4.6.4 Concluding remarks for sensitivity analysis.

4.6.4.1 Measure category 1: Transport cast/crew

The sensitivity analysis within this category uncovered notable variations across different parameters. The rental cost parameter exhibited a considerable disparity between the original results and the best- and worst-case scenarios, with the worst-case scenario even yielding negative outcomes. Similarly, when examining the sensitivity of diesel/petrol consumption rates, contrasting results were observed between the best- and worst-case scenarios. While the best-case scenario showcased a negative result, the worst-case scenario closely mirrored the original value (original: 42.50, worst-case: 30.75). Moreover, the sensitivity analysis for electric vehicle consumption rates demonstrated relatively minor deviations from the original analysis in the best-case scenario, with only a 7.5 value increase. However, in the worst-case scenario, a substantial negative difference of -201 compared to 42.50 was observed, emphasizing the significant impact of parameter variations.

4.6.4.2 Measure category 2(i): On-set Power, Low Carbon Fuel

The sensitivity analysis within Measure Category 2, focusing on on-set power and low carbon fuel, revealed slight differences in fuel consumption results across various scenarios. Specifically, when comparing the best- and worst-case scenarios to the original result of 6.70, minor disparities were evident. The best-case scenario yielded a result of 3.96, while the worst-case scenario showed a result of 8.28. These variations underscore the importance of considering different operational scenarios to accurately assess the implications of generator fuel consumption and optimize cost-effective strategies for emission reduction within this measure category.

4.6.4.3 Measure category 2(ii): On-set power, Battery

The sensitivity analysis indicates that specific costs rise with increased utilization of public charging facilities. Notably, results consistently remain negative across various scenarios, with minimal variation observed.

4.6.4.4 Measure category 5: Accommodation

In the assessment of accommodation-related costs and emissions, variations were observed across both parameters. Within the cost-variation, the sensitivity analysis revealed some disparity between the best- and worst-case scenarios, with costs ranging from 143 to 372, respectively, compared to the initial analysis value of 229.2. Similarly, concerning emission variation, the sensitivity analysis demonstrated a significant increase in specific costs, almost doubling to 406 compared to the initial analysis.

5. Discussion

Producing films and media sustainably is a complex task due to the diverse nature of productions. Each project varies in factors like location, scale, and technical requirements, leading to unique environmental footprints. The project's primary focus lies on mitigating emissions during the production phase of a series, simplifying management efforts. However, it is essential to acknowledge that emissions are not confined to this phase alone. The lifecycle of a series encompasses various stages, including pre-production, shooting, post-production, and distribution through streaming platforms, each contributing to its carbon footprint (Felder et al., 2008; Victory, 2015).

While efforts to reduce emissions during the production phase typically involve measures such as optimizing energy usage, transportation, and equipment efficiency, emissions occurring beyond this period, particularly during post-production and distribution via streaming platforms, present additional complexities (Marks & Radek Przedpełski, 2022). Post-production processes, coupled with the operation of cloud networks utilized by streaming platforms, contribute significantly to emissions and pose challenges in tracing and mitigating them (Marks & Radek Przedpełski, 2022). Therefore, while addressing emissions during the production phase serves as a pragmatic starting point, adopting a holistic approach that considers the entire lifecycle of the series is imperative. This approach entails collaborating with stakeholders across different stages, optimizing energy usage in post-production and streaming infrastructure, and exploring avenues for carbon offsetting to effectively mitigate emissions and reduce the series' environmental impact.

5.1 Mapping Stakeholder Connections and Impact Areas for Sustainable Production

This thesis project provides valuable insight into the complex metrics involved in the adaptation to a less carbon-intensive mode of film production across multiple levels. Firstly, this is demonstrated by addressing the need for a comprehensive understanding of the roles and connections among stakeholders and key figures responsible for sustainable practices within the AV production process.

While previous research has outlined these roles, this study recognized a gap in providing a depictive representation of these connections throughout the production period. Consequently, the project developed two figures illustrating the interconnectedness of departments, individuals, and their respective impact areas. This addresses the barrier identified by Keilbach & Spoler (2022) regarding the communication gap among industry professionals who are unsure about who should initiate “green” practices. These figures, depicted in section 2, figures 2 and 3, delineate departments between Above-the-Line (ATL) and Below-the-Line (BTL), each connected to the identified carbon impact areas. These impact areas were subsequently translated into measure categories analyzed in the MACC analysis. This included the production management department and locations department having considerable impact over the transport plan for both crew and materials, while production management had specific influence over the choice of rented accommodation. Additionally, the production office was responsible for energy use within the office, the electrical department was connected to energy use on set, and the art, costume, and makeup department were responsible for waste production and sorting for end-of-life use. Finally, the catering department had a particular impact over the types of meals served on-set. Furthermore, model building showcased a breakdown of emission production, categorizing emissions into scope 1, 2 and 3 emissions as well as upstream or downstream emissions, as demonstrated in section 2, Figure 4. This model enhances understanding of emission sources and aids in devising targeted mitigation strategies within the industry.

5.2 MACC Analysis: Bridging Knowledge and Practice

On another level, the results of the MACC also directly addressed barriers addressing both an academic and industry-level knowledge-gap on a national and European scale (SPA, 2021; Keilbach & Spoler, 2022; Interreg, 2020; Calaveras 2023; Schwarzenegger et al., 2006). This is referring to a lack of reliable academic information on the environmental impact of the AV industry (SPA, 2021; Interreg, 2020; Calaveras 2023; Schwarzenegger et al., 2006) as well as an industry-level disconnect between professionals, regarding their awareness of carbon mitigation practices and their effectiveness. (Keilbach & Spoler, 2022). This analysis confronts these barriers by creating a comprehensive outline of all available carbon mitigation practices within the industry. It delved deeper into the barrier by providing insight into the most cost-effective measures to reduce carbon emissions throughout the production process, focusing on five specific categories: transport of crew, on-set power, office power, catering, and rented accommodation. Therefore, results added value to the identified barriers by not only raising awareness of carbon mitigation practices but also providing actionable insights and tools to implement them effectively within the Dutch AV industry.

The analysis also reiterated findings in previous research which highlight the difficulty in standardizing and measuring impact industry-wide, due to inconsistent production parameters across media projects (Loy, 2020; Callebaut, 2022; Mohebi, 2022; Keilbach & Spoler; 2022; SPA, 2021; Victory, 2015; Kääpä & Kaźmierczak, 2022). This difficulty is particularly relevant within the sensitivity analysis, where results for measure categories under transport of cast/crew, on-set power and accommodation were particularly sensitive to alterations in uncertain parameters. Standardizing practices across the heterogenous nature of productions has the potential to be overcome by pooling resources and knowledge from both public and private entities and increasing awareness about the environmental impact within the industry. On a national level this is being supported by a local start-up called Green Screen, which is spearheading the first official training program for sustainability managers on-set by collaborating with the VAF (GreenScreen, 2023). The training program will comprise an overview on the sustainability within the AV industry by taking national case studies as examples for training (GreenScreen, 2023). The program will also provide a comprehensive list of suppliers and private collaborators that sustainability managers can contact to devise their carbon action plan for the production they are working on (GreenScreen, 2023).

In addition to this, further action can be taken by public entities to ensure awareness and adoption of sustainable practices on AV productions. This could be effective through building policies which mandate the inclusion of officially trained sustainability managers on each production. These managers would be responsible for devising and implementing sustainability plans, ensuring that these practices are properly integrated into all aspects of production. This requirement would not only ensure that sustainability is prioritized but also foster compulsory collaboration among AV departments and the sustainability manager. Furthermore, establishing a national official list of reliable suppliers and partners within key measure categories—such as transport, energy provision, catering, and accommodation—would provide sustainability managers with immediate access to trusted resources, facilitating smoother implementation of sustainable practices on set.

5.3 Overcoming Financial Barriers and Promoting Efficiency

The results of this research also support previous findings in that sustainable measures are usually substantially more expensive than the non-sustainable alternative. This was also an additional barrier pointed out by Keilbach & Spoler (2022) wherein a lack of financial support was noted in the Netherlands. The additional costs are observed in this study between the BAU and the sustainable production where there is an increase of around €50,000. However, it also demonstrates potential cost-savings within the on-set power category, particularly through the utilization of hybrid solar power cells and battery generators. These innovative technologies, although promising, face skepticism from longstanding industry professionals concerned about disruption to the production process. Therefore, it is recommended that national case studies are conducted to showcase the successful application of these technologies and identify areas of improvement in following productions. Once examples of use are made, this could encourage wider uptake of sustainable energy power sets throughout production.

Considering the additional costs involved, particularly for smaller, independent media projects struggling with funding, Bianciarelli et al. (2023) advise the employment of two strategies for improvement. In the short term, there needs to be an investment in time and money from the production company to address the added expenses associated with sustainable approaches, including the costs of green energy solutions and potentially extending working hours. While committed productions like Pupkin's tentpole TV series may absorb these costs, smaller projects may lack the financial means. On a macro level, eligibility for bonuses or subsidies processed by national public bodies in the industry can help offset these additional expenses (Bianciarelli et al., 2023). This is currently taking place in the Netherlands with the Film Funds' new policy for productions seeking funding, on the condition that they create a mandatory carbon calculation and associated development of a carbon action plan through Albert (Dijksterhuis, 2023).

In the long term, there should be a focus on cost reduction through sustainable practices. Sustainable filming should aim to be cost-neutral or even cheaper than traditional production methods. Transitioning to a more frugal model of production would involve moderation in production and resource consumption, leading to significant budget savings (Bianciarelli et al., 2023). Actions such as reducing travel, favoring second-hand items and rentals, and minimizing energy consumption contribute to this cost reduction. Over time, as sustainable models are adopted within private companies, external support may no longer be required.

5.4 Assessment of Research Quality and Associated Limitations

By considering the concepts of reliability and validity the quality of this research will be discussed hereunder. As previously mentioned, productions are heterogenous in nature, they are dependent on the context of the script's storyline which is considerably different from production-to-production (Loy, 2020; Callebaut, 2022; Mohebi, 2022; Keilbach & Spoler; 2022; SPA, 2021; Victory, 2015; Kääpä & Kaźmierczak, 2022). The MACC is a tool that can be reapplied over several different productions. However, the results are likely to differ as exemplified in the sensitivity analysis. Therefore, test-retest reliability is something that cannot be wholly ensured within the context of this analysis. One method to address the variability in results is to conduct multiple tests of the MACC across different productions at a national level and then compare the findings through a meta-analysis.

Validity, on the other hand, is an insurance of accuracy and relevance in measurement (Creswell & Creswell, 2023). When considering the validity of the project's content, the MACC was used to the best of its nature when considering the timeline of the analysis. If more time and resources were available, more MMs could have been assessed, and subsequently, a wider understanding of a tentpole's production carbon reduction potential could have been depicted. Therefore, it is recommended that repeat formats of the MACC are conducted, and additional MMs are measured which were ruled out due to time constraints and data availability to give a better understanding of the research question.

With the inclusion of more MMs comes a higher likelihood of dealing with interaction between such measures (Toman, 2008). For example, if the MM which describes optimizing an efficient transport plan under the measure category for transport of crew was chosen in addition to the MM describing the use of efficient vehicles, there would be clear interaction between the two measures. This can be seen on three levels. Firstly, their interaction could lead to cost savings. For example, by reducing travel distances through efficient transport planning, the operational costs associated with using electric vehicles, ie. Charging and maintenance may decrease. Conversely, if transport plans are not optimized, the higher costs associated with inefficient travel may offset the savings from using electric vehicles. Secondly, combining the use of electric vehicles and efficient logistical planning would significantly reduce GHG emissions. However, careful logistical planning would be required if these measures were to coexist. For example, the transport plan would have to consider the availability of charging infrastructure for EVs at filming locations and accommodation sites. With the inclusion of more MMs there is a greater chance of expressing a more significant reduction potential than that which was depicted in this analysis, therefore there is a possibility that this analysis underestimates the reduction potential of a Dutch tentpole TV series.

5.4.1 MACC-specific limitations

Expert-based, bottom-up MACCs built on static modelling present several limitations. This includes the subjectivity of expert opinions, the potential for overlooking certain mitigation measures, reliance on potentially outdated data, sensitivity to modeling assumptions, and the inability to capture dynamic changes over time. This research optimizes its methodology to overcome these limitations by seeking data input from diverse experts to minimize bias and conducts a sensitivity analysis to explore uncertainties. It is recommended that if this study was to be repeated that different scenarios be explored by altering key parameters such as technological advancements, regulatory changes, or market conditions to simulate various possible futures. These scenarios can help assess the robustness of the model and its sensitivity to different factors. Additionally, dynamic modeling techniques could be employed to capture the evolving nature of the film production industry over time. This could include dynamic simulation models that incorporate feedback loops, time delays, and non-linear relationships to better represent the complex dynamics of the industry. Furthermore, employing modeling techniques, such as Monte Carlo simulations, can account for uncertainties and variability inherent in the system, providing a more realistic representation of potential outcomes.

However, another significant limitation arises from the potential overlaps within a MACC. When multiple measures targeting the same emission sources or objectives overlap, there's a risk of double counting emission reductions (Kesicki & Strachan, 2011). This can distort the assessment of cost-effectiveness and emission reduction potential, leading to a skewed representation of the effectiveness of mitigation measures (Kesicki & Strachan, 2011). This is the case for the measure category, On-set power which uses three different types of MMs, one for the battery generator, low-carbon fuel and the hybrid generator. To address this, it's important to scrutinize the methodology used to construct the MACC and ensure that each measure's contribution is accurately represented without duplication. Additionally, sensitivity analysis and scenario testing can help identify and mitigate any potential overlaps, providing a more robust and accurate assessment of the cost-effectiveness of mitigation measures.

Another limitation that this approach introduces is that it also singularly includes direct financial costs and does not account for indirect, non-financial costs and productivity benefits of CO_2 abatement (Huang etal., 2016; Worrell et al., 2003). The exclusion of such data can significantly alter the cost-analysis of the technology, resulting in a skewed evaluation of MMs, and potential overestimation of abatement potential (Almihoub et al., 2013; Worrell et al., 2003). To improve future research, it is recommended that a MACC model is built to incorporate indirect, non-financial costs and account for a more representative result.

6. Conclusion

There has been a heightened awareness of the imperative for companies to assume responsibility for mitigating climate change, particularly due to their substantial contributions to greenhouse gas emissions. As significant emitters, companies wield considerable influence over global carbon footprints, making their commitment to sustainability pivotal in combating climate change. In response, the audiovisual sector is increasingly recognizing the importance of sustainability, with initiatives emerging to mitigate its environmental footprint. Consequently, there is a pressing need to comprehensively assess the environmental impact of the audiovisual industry.

This research adds value to insight on environmental impact of the AV industry within the scope of the Netherlands by answering the research question

What is the potential for CO_2 emission reduction and related marginal costs for a (tentpole) AV production in The Netherlands?

This was addressed by building a MACC based on a tentpole TV series produced by Pupkin, a Dutch production company. The MACC provided a systematic framework for assessing various MMs that could potentially reduce CO_2 emissions throughout the production process. By quantifying the potential emission reductions and their corresponding marginal costs, the MACC facilitated a ranking of 7 different sustainability strategies that fall under 5 measure categories (see section 3, Figure 5) based on their feasibility and cost-effectiveness within the context of the Dutch AV industry.

Results showed that potential cost-savings could be made by switching to battery-powered or hybrid-solar generators on-set instead of traditional, diesel-powered generators on-set but requires real-world application as exemplary models. Negative costs were also shown under the Office Power measure category, by switching to a green electricity provider. The other 4 MMs showed significant abatement potential, some having more impact than others, but marginal costs were all positive when compared to the BAU. Specifically, the most emissions were saved in Transport for crew measure, however specific costs are still positive. The MM with the second highest abatement potential, was green-certified accommodation, but costs associated with this considerably increased. This was followed by and low carbon fuel generator.

The sensitivity analysis also showed how marginal costs and abatement potential are multi-factor dependent, with uncertain parameters having significant impact on results. This emphasizes the need for a study which compiles data from several productions in the form of a meta-analysis.

This project strives to broaden existing insight into the carbon mitigation efforts that exist within the Dutch AV industry. Results showed where most carbon mitigation efficiency exists within the 5 measure categories assessed. In some cases, it shows that sustainability does not necessarily require extra costs but can have the potential to reduce financial spending while simultaneously reducing emissions.

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9. Appendix

Appendix A – Tables for Methodology

Table 1

Selection criteria of activities in SC based on GHG Protocol (2013).

Selection criteria	Description of impacting activities
Size	Significant contribution to Pupkin's total scope 3 emissions.
Influence	MMs exist to counter emissions of the activity.
Risk	It contributes to Pupkin's risk exposure (e.g., climate change related risks such as financial, regulatory, supply chain, product and technology, compliance/litigation, and reputational risks)
Stakeholders	Considered critical by main internal and external stakeholders (e.g. investors or civil society)
Sector guidance	Identified as significant by sector-specific guidance
Spending or revenue analysis	Permit a high amount of spending or create a high level of profit (and are sometimes correlated with high GHG emissions)

Table 3

Data required for measuring cost-effectiveness

Category	Qual/Quant	Data point name	Data point description	Unit	Source
For BAU	Qual	Reasoning for BAU	How the BAU was derived	/	Academic or industry publications
For BAU	Qual	Assumption	Explains how each category is worked out and where the cost data is retrieved from. Any additional notes about the categroy are included here.	/	/
For BAU	Quant	Rental costs per day	Costs were worked out over 126 day period, hence daily rental costs were specified for further calculations.	€ in 2023	Communication with industry professionals and desk research.
For BAU	Quant	Fuel & operational costs (current)	Any additional costs associated with the upkeep and use of the MM	€ in 2023	IEA (Owen et al, 2018)

For BAU	Quant	Total costs of BAU	The total costs involved when renting the BAU over 126 days of shooting	€ in 2023	Academic or industry sources specific to the measures; OR test data
For BAU	Quant	Carbon emissions	Emissions calculated using **Albert Calculator -** carbon calculator specific to the audio-visual production industry	t of CO_2eq	https://wearealbert.org/carbon-calculator-and-production-certification/
For each MM	**Qual**	**Reasoning for MM**	**Literature which recommends MM**	**/**	**Academic or industry publications**
For each MM	Qual	Assumption	Explains how each category is worked out and where the cost data is retrieved from. Any additional notes about the categroy are included here.	/	/
For each MM	Quant	Rental costs per day	Costs were worked out over 126 day period, hence daily rental costs were specified for further calculations.	€ in 2023	Communication with industry professionals and desk research.
	Quant	Fuel & operational costs of a MM	Any additional costs associated with the upkeep and use of the MM	€ in 2023	" "
For each MM	Quant	Total costs over shooting period	The total costs involved when renting the MM over 126 days of shooting	€ in 2023	Academic or industry sources specific to the measures; OR test data
For each MM	Quant	Carbon emissions	If not mentioned, assume that emissions are calculated using **Albert Calculator -** carbon calculator specific to the AV production industry. If the calculator does not have options for a MM - an estimated emission amount was retrieved from MM provider/company which will	tCO_2eq	(Albert, 2021)

			be mentioned in the "assumptions" column.		
For each MM	Quant	Emission savings	The amount of emissions reduced by implementing MM when compared to BAU	% of t of CO_2	From accrued data.
For each MM	Quant	Specific costs	Marginilized costs and emissions of MM by comparig to BAU to create data input for curve.	€/t CO_2e.	" "

Appendix B – Calculations for BAU scenarios and MMs

Section 1 – Calculations for BAU

Measure Category 1 - Transport BAU

Costs

Total rental costs over shooting period

Sum of total rental price per vehicle type (€) found in Table X

136,080 + 27,720 + 27,720 = 191,520

Fuel & operational costs

Sum of fuel consumption costs (€) found in Table X

31606.848 + 1014.8256 + 16913.76 = 49535.43

Total costs

Total rental costs over shooting period (€) + Fuel & operational costs (€)

49535.4336 + 191520 = 241055

Carbon emissions (tCO_2eq)

Data input in Albert Calculator

Type of transport, Type of fuel, Distance (km)

Mercedes Sprinter (Double Cabin)

- Van, Diesel, 192000 = 55.78

Nissan Micra [B] other

- Car, Gasoline/petrol, 9600 = 1.66

Nissan Micra [B] PA car

- Car, Gasoline/petrol, 160000 = 27.73

Total emissions (tCO_2eq)

Sum of carbon emissions per vehicle type

55.78 + 1.66 + 27.73 = 85.17

Measure Category 2 - OsP BAU

Costs (€)

Rental costs over shooting period:

Rental costs per day (€)*Total shooting period (days)

250*126 = 31500

Fuel & Operational Costs

- **Cost of diesel for generator:**

Total shooting period (days)*(Diesel price [€/L]* Fuel requirement/day [L])

126*(1.809*30L) = 6838.02

- **Cost of diesel for transporting generators between locations:**

Fuel consumption of truck (L)* Diesel price (€/L)

426.60*1.809 = 771.72

Total costs:

Rental costs + Fuel & Operational Costs

31500 + 6838.02 + 771.72 = 39109.74

Carbon emissions (tCO_2eq)

Data input in Albert Calculator

- **Direct emissions from generator:**

Type of fuel (diesel), Fuel requirement/day (L), Actual shooting period (days) = 5.51

- **Emissions from transporting generator between locations:**

Type of transport (>3.5t heavy goods vehicle [HGV]), Type of fuel (diesel), Total distance between shooting locations (km) = 0.87

Total emissions

Direct emissions from generator + Emissions from transporting generator between locations:

5.51 + 0.87 = 6.38

Measure Category 3 - Office Energy BAU

Total costs over shooting period

Average monthly price (€) found in Table X*4 months

420.69*4 = 1682,76

Total carbon emissions (tCO_2eq)

Data input in Albert Calculator

Type of non-filming space, energy type, measurement type, number of employees, number of days, renewable electrcicty source: yes or no?

Production Office, Electricity, Benchmark: Air-conditioned (Prestige/HQ), 49, 126

= 15.02

Measure Category 4 – BAU Accommodation

Costs

Total costs over shooting period

Total costs (€) over 3 shooting blocks found in Table X

203,880

Carbon emissions

Total carbon emissions (tCO_2eq)

Data input in Albert Calculator

Number of nights, number of rooms, type of accommodation, certified accommodation or not

72, 20, upscale hotel, no

Measure Category 4 – MM Accommodation

Costs

Total costs over shooting period

Total costs (€) over 3 shooting blocks found in Table X

222,600

Carbon emissions

Total carbon emissions (tCO_2eq)

Data input in Albert Calculator

Number of nights, number of rooms, type of accommodation, certified accommodation or not

72, 20, upscale hotel, yes

Measure Category 5 - BAU Catering

Costs

Total costs over shooting period

Total costs (€) over 3 shooting blocks found in Table X

13,252.84

Carbon emissions

Total carbon emissions (tCO_2eq)

Data input in Albert Calculator

Type of meal, number of meals

Lamb, beef, chicken, pork, fish, 2320

Section 2 – MM calculations

Measure Category 1 - Transport MM

Costs

Total rental costs over shooting period

Sum of total rental price per vehicle type (€) found in Table X

145530 + 55440 + 27720 = 200970

Fuel & operational costs

Charging costs

Sum of total charging costs (€) found in Table X

28274.40 + 891 + 14256 = 43421.40

Total costs

Total rental costs over shooting period (€) + Fuel & operational costs (€)

200970 + 43421.40 = 244391.40

Carbon emissions (tCO_2eq)

Data input in Albert Calculator

Type of transport, Type of fuel, Distance (km)

Mercedes Sprinter (Double Cabin)

- Van, electric, 168000 = 12.85

Nissan Micra [B] other

- Car (large), electric, 9600 = 11.41

Nissan Micra [B] PA car

- Car (large), electric, 160000 = 0.68

Total emissions (tCO_2eq)

Sum of carbon emissions per vehicle type

12.85 + 11.41 + 0.68 = 24.94

Measure category 2 - OsP MM – Battery Powered Generator

Costs (€)

Rental costs over shooting period (€):

Rental costs per day (€)* Total shooting period (days)

125.57*126 = 15822

Fuel & Operational costs (€):

- **Transportation costs from and to rental company (**€)

Input from rental company = 400

- **Diesel for transporting battery between locations (**€)

Input from BAU = 771.72

- **Charging costs (**€)

Cost intensity of kWh * energy consumption * 57 charging sessions

0.475*109.38 = 51.95*57 = 2961.46

Total costs (€):

Rental costs over shooting period (€) + Fuel & Operational Costs (€)

15,822 + 400 + 771.72 + 2961.46 = 21340.28

Carbon emissions (tCO_2eq)

Carbon emissions from charging battery (tCO_2eq)

Emissions from transporting generator between locations (tCO_2eq)

Input from BAU = 0.87

Total emissions

Carbon emissions from charging battery (CO_2eq) + Emissions from transporting generator between locations (tCO_2eq)

3.26 + 0.87 = 4.13

Emission savings

100 - (100)*(Total emissions MM/Total emissions BAU)

35.16

Specific Costs

(Total costs MM – Total costs BAU)/Emission savings

-400.37

Measure Category 2 - OsP MM - Hybrid solar battery and bio-fuel generator

Costs (€)

Rental costs over shooting period (€):

Rental costs per day (€)* Total shooting period (days)

74.31*126 = 9,363.60

Fuel & Operational costs (€):

4. **Transportation costs from and to rental company (**€)

Input from rental company = 377.64

5. **Diesel for transporting battery between locations (**€)

Input from BAU = 771.72

Total costs (€):

Rental costs over shooting period (€) + Fuel & Operational Costs (€)

9,363.60 + 377.64 + 771.72 = 10,512.96

Carbon emissions (tCO$_2$eq)

Carbon emissions from direct use of generator (tCO$_2$eq)

Actual shooting period (days)* Emissions from hybrid generator per day (tCO$_2$eq)

58* 0.02275 = 1.32

Emissions from transporting generator between locations (tCO$_2$eq)

Input from BAU = 0.87

Total emissions

Carbon emissions from hybrid generator (tCO$_2$eq) + Emissions from transporting generator between locations (tCO$_2$eq)

1.32 + 0.87 = 2.19

Emission savings (%)

100 - (100)*(Total emissions MM/Total emissions BAU)

100 - (100)*(2.19/5.51) = 60%

Specific Costs

(Total costs MM – Total costs BAU)/Emission savings

(10,512.96 - 39,109.74)/60 = -119

Measure Category 2 - OsP MM - Traditional generator with low carbon fuel

Costs (€)

Rental costs over shooting period (€):

Rental costs per day (€)* Total shooting period (days)

250*126 = 14,500

Fuel & Operational costs (€):

- **Total cost of HVO100 fuel (**€)

HVO100 fuel price (€/L)* **Fuel requirement/day (L)*** Total shooting period (days)

2.0851*30*126 = 3,628.07

- **Diesel for transporting battery between locations (**€)

Input from BAU = 771.72

Total costs (€):

Rental costs over shooting period (€) + Fuel & Operational Costs (€)

31,500 + 3,628.07 + 771.72 = 35,899.79

Carbon emissions (tCO_2eq)

- **Carbon emissions from direct use of generator(tCO_2eq)**

Data input in Albert Calculator

Type of fuel (diesel), Fuel requirement/day (L), Actual shooting period (days) = 0.67

- **Emissions from transporting generator between locations (tCO_2eq)**

Input from BAU = 0.87

Total emissions

Carbon emissions from hybrid generator (tCO_2eq) + Emissions from transporting generator between locations (tCO_2eq)

0.67 + 0.87 = 1.54

Emission savings (%)

100 - (100)*(Total emissions MM/Total emissions BAU)

100 - (100)*(1.54/5.51) = 72%

Specific Costs

(Total costs MM – Total costs BAU)/Emission savings

(35,899.79 - 39,109.74)/72 = 6.7

Measure Category 3 - Office Energy MM

Costs

Total costs over shooting period

Average monthly price (€) found in Table X*4 months

393.35*4 = 1573.39

Carbon emissions

Total carbon emissions (tCO$_2$eq)

Data input in Albert Calculator

Type of non-filming space, energy type, measurement type, number of employees, number of days, renewable electricity source: yes or no?

Production Office, Electricity, Benchmark: Air-conditioned (Prestige/HQ), 49, 126, yes

= 0

Measure Category 5 - MM Catering

Costs

Total costs over shooting period

Total costs (€) over 3 shooting blocks found in Table X

13,682.68

Carbon emissions

Total carbon emissions (tCO$_2$eq)

Data input in Albert Calculator

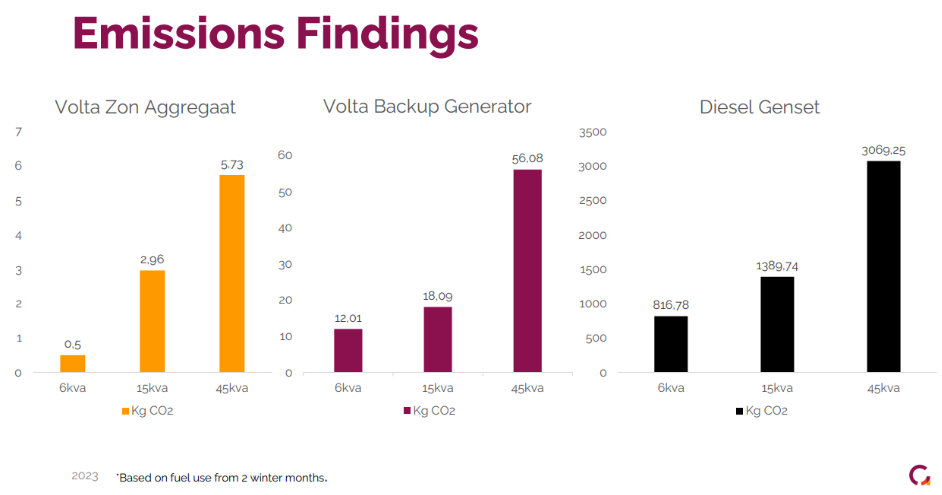
Type of meal, number of meals

Vegan, vegetarian, 2320

Appendix C – Emissions from Hybrid generator

Figure 1

Graph of emissions emitted by Volta's hybrid generator during the annual period with lowest amount of sun hours



Emissions Findings

2023 *Based on fuel use from 2 winter months.