Memorandum

Comparison of GHG Emissions from Scenes of On-Location and Virtual Productions

Virtual productions utilize virtual set technology combined with physical set elements to produce films and TV shows. Studios film on a stage with an LED panel array background to capture a virtual location rather than filming on-location.

ICF conducted an analysis to compare the emissions from on-location shoots and virtual production shoots for scenes from two television shows. The analysis was based on data describing the resources used (e.g., electricity, fuel for generators, transportation of crew and cast, etc.) for on-location shoots from two TV shows, called Production A and Production B in this analysis, and data estimating the resources needed if these same five scenes had been filmed using a virtual production process and stage. Table 1 presents descriptions of the TV shows and scenes used in this analysis.

This memorandum describes the methodology, assumptions, results, and limitations. The data collected to conduct this analysis are summarized in the Appendix.

Table 1: TV Show Descriptions

	Production A	Production B
TV Show Category	1-hour scripted drama	1-hour scripted drama
Filming Location	College campus in British Columbia, Canada	Horse stables in the United Kingdom
Scene Details	Three scenes shot at one location: • Scene 1: Interior Cafeteria. Character drinking a drink sitting with another character and they talk. • Scene 2: Exterior Breezeway. Character walks out to see other character sitting alone on a bench and they talk. • Scene 3: Interior Waiting Room. Two characters sit alone and talk.	Two scenes shot at one location: • Scene 1: Exterior Stables. Two characters walk to and enter stables. They look at a horse, get into a physical altercation, another character walks in. • Scene 2: Interior Stables. Two characters talk in the stables.
Scene Data Details	Data reflects one day that includes physical prep, shoot, and wrap.	Data reflects 11 days that include physical prep (7 days), shoot (2 days), and wrap (3 days). There was some overlap between prep, shoot, and wrap activities within those days.

Methodology

The TV shows and scenes described in the table above were selected for this analysis because of their differences in location, relative proximity to a stage which minimizes long travel distances for

crews during the on-location shooting process that often benefits virtual production, and the availability of data.

ICF received details on building square footage, electricity consumption, types of vehicles, distance traveled by vehicles, fuel used by generators, hotel stays, and waste generation related to the production of the on-location scenes and similar estimations for the same scenes captured in a virtual production environment. For the virtual production scenarios, ICF also received details on the size of a virtual production stage and energy use including the LED panels and rendering of images and scenes, given the virtual production process can include traditional post-production activities in the prep and shoot phases. This data was used to calculate the emissions of the on-location and virtual production versions of these scenes. A summary of the data can be found in the Appendix.

The analysis followed the GHG Protocol for using emission factors to calculate the emissions in the unit metric tons of carbon dioxide equivalent (MT CO_2e) related to different activities, such as the combustion of fuel by a vehicle or the generation of electricity. The emissions were categorized as Scope 1, Scope 2, and Scope 3 emissions. Scope 1 emissions are direct emissions related to stationary and mobile combustion of fuel and refrigerant use. Scope 2 emissions are indirect emissions related to the production of electricity. Scope 3 emissions are all other indirect emissions, such as emissions that occur from the disposal of waste and emissions related to hotel stays.

Scope and Boundaries

The scope and boundaries of this analysis only included activities and emissions directly related to the prep, wrap, and shoot of the scenes between the studio and the filming locations. Therefore, emissions such as commuting to the studios from home or to the filming location from home by crew, contractors, and cast were considered out of scope. Within the studios and filming locations, emissions were only calculated for the area of the buildings related to the scenes, such as the square footage of the virtual production stage or the square footage of the rooms used for on-location filming. Emissions related to editing footage, digitizing on-location capture footage, re-shoots, and post-production work associated with the scenes were excluded from this analysis.

Assumptions

Due to incomplete or missing data, ICF made assumption to fill data gaps to complete the analysis.

Table 2: Assumption by Data Category

Data Category	Assumptions
Film Date	• Although the scene from Production B was originally shot in 2019, this analysis assumed it was filmed in 2021 to make more accurate comparisons between the Production B scene and Production A scene, which was filmed in 2021.
Vehicles	• When direct fuel consumption was not provided for vehicles, fuel use was estimated based on the reported distance the vehicles traveled during prep, shoot, and wrap days and the fuel efficiency based on the year, make, and model of the vehicle as reported on EPA's FuelEconomy.gov or an average fuel efficiency based on the type of vehicle (i.e., car, SUV, van, etc.).

	• If the year of a vehicle was not reported, it was assumed to be a 2020 vehicle. • When vehicle fuel type was not reported, it was assumed to be the most common types of fuel per vehicle (i.e., most cars use gasoline).
On-Location Electricity Use	• Emission factors for electricity use were based on the location of the scenes or the location of studios. • Electricity consumption was estimated on an electricity use per square footage basis. Electricity use for Production A's studio assumed Sony Pictures Studio's average electricity consumption per square foot estimate for a stage (4.8 kilowatt hours per square foot) and electricity use for Production B's studio was based on the electricity use per square foot derived from data collected from the local studio's annual GHG inventory. • Electricity use for filming locations in a building assumed an electricity use per square foot estimate from the U.S. Energy Information Administration's 2012 Commercial Building Energy Consumption Survey (CBECS).
Air Travel	• No air travel emissions were included in this analysis because the scenes analyzed were filmed in the same country as the production studio, therefore only ground transportation was used to transport crew and equipment.
On-Location Capture	• It was assumed that on-location capture contractors were already in-country and that the contractor drove the same distance to the location as the crew members for an on-location shoot. Therefore, no emissions were calculated for initial travel to the studio for the contractors. • Emissions were not calculated for the distance traveled by contractors going to the location from their hotels and back, as it was assumed that the hotels were close enough to the location where the emissions from that travel would be negligible.
Virtual Production Stages	• Although the studios for both Production A and Production B do not currently have virtual production stages, it was assumed that both studios had a virtual production stage for the purpose of estimating emissions. This assumption minimizes a potentially wide range of travel scenarios based on an unknown origin when comparing traditional on-location and virtual production shoots. • Estimates for the square footage of the stage, the size of the LED panel array, and the amount of time that the panels were in use or idling were provided by Sony. • The average energy use of one LED panel when in use of 58 watts was based on the specifications of the panels as provided by Sony. The average power consumption per panel was used to estimate energy use for the entire LED panel array. It was assumed that the panels were in use 70% of the time during prep hours, 100% of the time during shoot hours, and 0% of the time during wrap hours.

	• However, it was noted that even when the panels were not being used, they are in stand-by mode, not completely off. In stand-by mode, the panels draw 0.1 watts based on data provided by Sony. It was assumed that the panels were in standby mode during 30% of the time during prep hours, 0% of the time during shoot hours, and 100% of the time during wrap hours. It was assumed that the panels were in stand-by mode during non-working hours (i.e., overnight). • The average electricity load of the render nodes and compute equipment, display signaling layer, and networking equipment to manage the data layer were provided by Sony. The average load provided was 25.6 kilowatts when in use and 11 kilowatts when idle. It was assumed that the rendering equipment were in use during prep and shoot hours and idle during wrap hours and during non-working hours (i.e., overnight). • Emissions from Production B's studio were captured as part of Sony Pictures' 2021 GHG inventory. The data and emissions from the GHG inventory are used to estimate emissions from the studio based on the square footage and days during which the virtual stage would be used in the virtual production scenario.

Results

A comparison of total emissions from each production scenario shows that scenes produced using virtual production technology have emissions reduction potential. Table 3 summarizes the GHG emissions by scope and emission source for the on-location and virtual production scenarios for Productions A and B. Table 4 compares the total emissions for the on-location and virtual production scenarios.

The GHG emissions from Virtual Production A were estimated to be 0.61 MT CO_2e, 80% lower than the GHG emissions from On-Location Production A, which were estimated to be 3.09 MT CO_2e. The emissions from On-Location Production A were driven by on-site fuel combustion and vehicle fuel combustion, both small emissions sources for Virtual Production A.

Similarly, the GHG emissions from Virtual Production B were estimated to be 4.01 MT CO_2e, 76% lower than the GHG emissions from On-Location Production B which were estimated to be 16.47 MT CO_2e. The emissions from On-Location Production B were driven by vehicle fuel combustion and hotel stays, both very small emissions sources for Virtual Production B.

For both virtual production scenarios, the electricity consumption by the LED panel array was a primary contributor to overall emissions, but those emissions were less compared to the on-location scenario emissions.

Table 3: Summary of Emissions by Scope for On-Location and Virtual Productions of Scenes from Production A and Production B

	Production A		Production B	
	On-Location	Virtual Production	On-Location	Virtual Production
	MT CO_2e	MT CO_2e	MT CO_2e	MT CO_2e
Scope 1*	**2.92**	**0.22**	**12.33**	**0.15**
On-Site Fuel Combustion	1.59	0.19	1.50	0.04
Vehicle Fuel Combustion	1.10	<0.01	10.81	0.07
Refrigerants	0.23	0.03	0.02	0.04
Scope 2[a]	**<0.01**	**0.06**	**0.00**	**2.05[b]**
LED Panel Array Purchased Electricity	N/A	0.04	N/A	1.46
Virtual Stage Purchased Electricity	N/A	<0.01	N/A	0.09
Rendering Equipment Purchased Electricity	N/A	0.01	N/A	0.50
Filming Location Purchased Electricity	<0.01	N/A	IE[c]	N/A
Scope 3	**0.17**	**0.33**	**4.15**	**1.81**
Hotel Stays	0.00[d]	0.27	2.59	0.25
Waste	0.17	0.06	1.56	1.56[e]
Total	**3.09**	**0.61**	**16.47**	**4.01**

[a] *This analysis utilizes location-based GHG emissions from purchased electricity. Market-based electricity emissions can be provided upon request.*

[b] *Production B's studio used 100% renewable electricity, but emissions from renewable electricity are not included in this analysis in order to provide a conservative comparison between on-location and virtual production scenarios.*

[c] *Included elsewhere (IE) - Electricity necessary for On-Location Production B was provided by on-site fuel sources.*

[d] *Hotel stays emissions are zero MT CO_2e because no hotels were used.*

[f] *Because the total build of physical set elements in Virtual Production B was unknown, to be conservative the same amount of set waste as On-Location Production B was assumed.*

Table 4: Total Emissions Comparison

Production	On-Location Production Total Emissions	Virtual Production Total Emissions	% Difference Between Virtual Production and On-Location Production
	MT CO_2e	MT CO_2e	
Production A	3.09	0.61	-80%
Production B	16.47	4.01	-76%

Production A

The largest source of emissions for On-Location Production A was on-site combustion from generators, heating, and natural gas consumed by the filming location building. The second largest source of emissions was fuel combustion used in vehicles transporting cast, crew, and equipment for the production. Although each individual vehicle drove a relatively short distance between the studio and the filming location, 133 gasoline-fueled vehicles were used over the course of the production.

The largest source of emissions from Virtual Production A was hotel stays. Contractors doing on-location capture booked a total of 20 room-nights to capture necessary footage to use in the virtual production studio. The second largest source of emissions from Virtual Production A was combustion of natural gas used in the portion of the Production A's studio facility occupied by the virtual production stage during the production days.

Production B

The largest source of emissions for On-Location Production B was fuel combustion from vehicles used for the production. A total of 27,119 miles were driven by gasoline-fueled vehicles during the production. The second largest source of emissions for On-Location Production B was hotel stays, as a total of 199 room-nights were booked during the production to accommodate cast, crew, and contractors.

The largest emission source for Virtual Production B was waste generation. Because the total build of physical set elements in Virtual Production B was unknown, to be conservative, the same amount of set waste as On-Location Production B was assumed. The second largest source for Virtual Production B was the electricity consumption by the LED panel array used at the virtual production stage. Although Virtual Production A and Virtual Production B used identical LED panel arrays for relatively similar amounts of time, the location-based emission factor for purchased electricity used in Production B is much higher than the location-based emission factor used in Production A, resulting in electricity consumption being a more significant driver of emissions for Production B than Production A. Both locations were assumed not to be powered by renewable electricity.

Comparison of Emissions Intensities

A comparison of emissions per production day shows that on-location productions tend to be more emissions-intensive than virtual productions, as shown in Table 5.

Table 5: Emissions per Production Day Comparison

Production	On-Location Production Emissions per Production Day	Virtual Production Emissions per Production Day	% Difference Between Virtual Production and On-Location Production
	MT CO_2e/Day	MT CO_2e/Day	
Production A	3.09	0.12	-96%
Production B	1.50	0.67	-55%

A comparison of emissions per shoot day also shows that shoot days for on-location productions tend to be more emissions-intensive than virtual productions, as shown in Table 6.

Table 6: Emissions per Shoot Day Comparison

Production	On-Location Production Emissions per Shoot Day	Virtual Production Emissions per Shoot Day	% Difference Between Virtual Production and On-Location Production
	MT CO_2e/Shoot Day	MT CO_2e/Shoot Day	
Production A	3.09*	0.31	-90%
Production B	8.24	2.00	-76%

**Time spent shooting could not be disaggregated because prep, shoot, and wrap all occurred within one day for this scene of Production A.*

The on-location productions and virtual productions examined in this analysis required similar numbers of cast, crew, and contractors, resulting in the emissions per person being lower for virtual production than for on-location productions, as shown in Table 7.

Table 7: Emissions per Person Comparison

Production	On-Location Production Emissions per Person	Virtual Production Emissions per Person	% Difference Between Virtual Production and On-Location Production
	MT CO_2e/Person	MT CO_2e/Person	
Production A	0.02	<0.01	-77%
Production B	0.14	0.04	-72%

Limitations and Future Analysis

This analysis of emissions for on-location and virtual productions only examined the emissions resulting from filming three scenes in one episode of Production A and two scenes in one episode of Production B. The results of this analysis may be representative of productions with similar resource and personnel needs, but due to this small sample size and the great variability of resources and personnel that may be required to produce other types of TV shows and scenes, the results of this analysis should not be generalized for every virtual production.

The scope of the analysis covers the prep, shoot, and wrap portion of a production. Expanding the scope of future studies to include the life cycle of materials such as set construction materials, the LED panel array, and the reuse of stored virtual filming locations and set pieces would be valuable. Another area to include in a future analysis is post-production. The virtual production process can alter the traditional process of content captured on a set that is then delivered to a post-production team. In a virtual production, activities traditionally done in post-production are often done in the pre-production and production stages. Analyzing the post-production process also will inform the differences between virtual production as opposed to content captured on a green screen. The choice creates differences both in the content capture and post-production processes.

Appendix

Table 8: Summary of General Production Information and Emission Source Data for Production A and Production B

Scope	Emission Category	Production A		Production B	
		On-Location	Virtual	On-Location	Virtual
N/A	**General Information: Production Days**	Total production days: 1 Time spent shooting could not be disaggregated because prep, shoot, and wrap all occurred within one day for this scene of On-Location Production A.	Prep days: 2 Shoot days: 2 Wrap days: 1 Total production days: 5	Prep days: 7 Shoot days: 2 Wrap days: 3 Total production days: 11 Prep, shoot, and wrap for On-Location Production B occurred over the course of 11 days, but there was overlap between prep, shoot, and wrap activities within those days.	Prep days: 3 Shoot days: 2 Wrap days: 1 Total production days: 6
N/A	**General Information: Personnel**	Crew, including contractors: 129 Cast: 4	Crew, including contractors: 111 Cast: 4	Crew, including contractors: 112 Cast: 5	Crew, including contractors: 97 Cast: 5
1	**On-Site Fuel Combustion**	4 generators consuming a total of 152.69 gallons of diesel; 19 gallons of propane consumed for heating for crew; 0.19 GJ of natural gas consumed for heating for 25,000 sq ft of filming location building	3.73 GJ of natural gas consumed at virtual production stage in studio	2 generators consuming a total of 550 litres of diesel	7.07 GJ of natural gas consumed at virtual production stage in studio

1	**Refrigerants**	R-410A and HCFC-22 refrigerant leaked for 25,000 sq ft of filming location building; Assumed refrigerant leaked from vehicles	R-410A and HCFC-22 refrigerant leaked at virtual production stage in studio; Assumed refrigerant leaked from vehicle	Assumed refrigerant leaked from vehicles	R-410A refrigerant leaked at virtual production stage in studio; Assumed refrigerant leaked from vehicles
1	**Vehicle Fuel Combustion**	100 passenger vehicles consuming 26.55 gallons of gasoline and traveling a total of 608 miles, 1 bus consuming 0.98 gallons of gasoline and traveling a total of 6.08 miles, and 32 other vans and SUVs consuming 19.10 gallons of gasoline and traveling 206.72 miles used to transport cast, crew, and equipment, consuming 75.78 gallons of gasoline consumed by vehicles on-site	1 car for transporting contractors to and from location for location capture, consuming 0.43 gallons of gasoline and traveling a total of 10 miles	25,154.4 total miles driven and 1,093.67 gallons of gasoline consumed by cars, 328 total miles driven and 52.95 gallons of gasoline consumed by buses, 1,636.8 total miles driven and 109.12 gallons of gasoline consumed by vans to transport cast, crew, and equipment	1 car for transporting contractors to and from location for location capture, consuming 7.83 gallons of gasoline and traveling a total of 180 miles
2	**Purchased Electricity**	92.94 kWh of electricity consumed for 25,000 sq ft filming location building	611.66 kWh of electricity consumed at the 7,752 sq ft virtual production stage in studio; 7,650.77 kWh of electricity consumed by the 2,400 LED panel array and rendering equipment, running for 40.8 hours	Electricity necessary for On-Location Production B was provided by generators	441.87 kWh of electricity consumed at the 7,752 sq ft virtual production stage in studio; 9,217.99 kWh of electricity consumed by the 2,400 LED panel array and rendering equipment running for 49.2 hours

			and in standby mode for 79.2 hours		and in standby mode for 94.8 hours
3	**Hotel Stays**	*No hotels were used*	20 room-nights at an economy to midscale segment hotel	111 room-nights at economy and midscale segment hotels, 63 room-nights at upper midscale segment hotels, and 25 room-nights at upscale and upper upscale segment hotels	20 room-nights at an economy to midscale segment hotel
3	**Waste**	660.6 lbs. of landfill waste generated	30 lbs. of landfill waste generated during on-location capture; 214.2 lbs. of recycling waste. 81.6 lbs. of recycling waste, and 214.2 lbs. of compost waste generated at the virtual production stage	6,000 lbs. of landfill waste generated	Assumed same amount of set waste as On-Location Production B at 6,000 lbs. of landfill waste generated