Quantifying the Life Cycle Environmental Impacts of Video-on-Demand Streaming: The Influence of Consumer Behavior

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Introduction

Video-on-demand (VoD) is a rapidly growing media distribution service that enables digital access to films and television series on user request. These services significantly contribute to environmental impacts, being **energy-intensive** (particularly in data centers and consumers' devices) and **material-intensive** (due to hardware manufacturing and disposal).

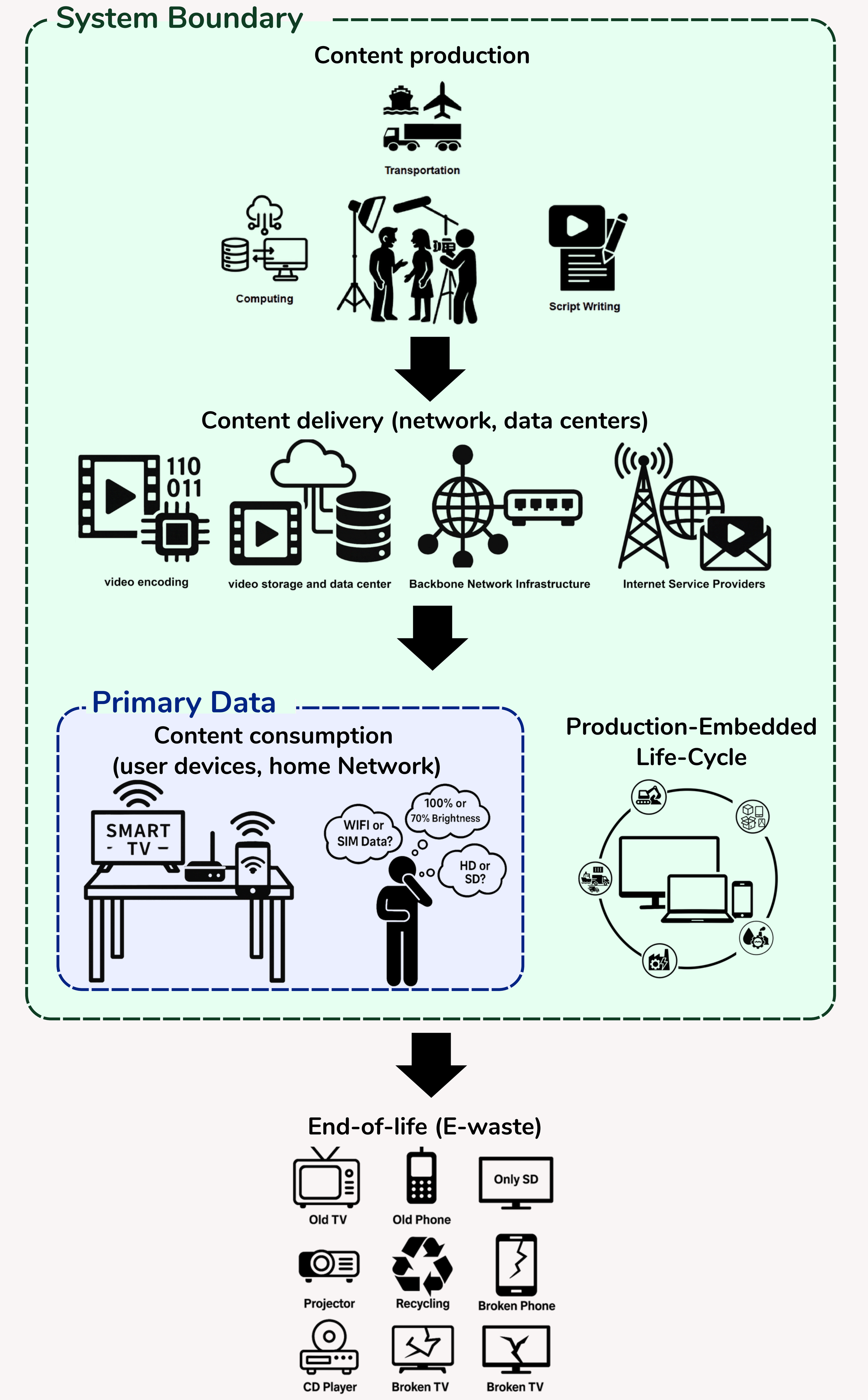
Motivation

- Data networks and transformations consume **1.5 % of global electricity**, mostly for video streaming, which carries **65 to 80 % of Internet traffic** [1,5].
- Globally, users consume approximately **833 hours** of video streaming annually per capita, causing **40–52%** of digital content's environmental impacts[2].
- Everyday digital use already consumes **40 % of a 1.5 °C carbon budget** and **55 % of the mineral resource** limit per person [2].
- Despite the significant environmental impacts of digital content consumption, the **influence of user behavior** on VoD's footprint remains poorly understood.

Objectives

1. To quantify the influence of **user behaviors** within the **content consumption** stage of VoD streaming on energy consumption.
2. The study aims to **identify practical strategies** to reduce these impacts through scenario-based analysis.

Full VoD Life Cycle



Study Approach - Key Points

- **Scenario-based Life Cycle Assessment (LCA):** evaluates how user-controlled settings during the content-consumption stage shift energy use and emissions.
- **Functional unit:** 1 hour of streaming for one user.
- **Baseline check:** an online user survey captured current streaming habits to anchor the reference scenario.
- **Impact calculation:** measured energies feed into Life Cycle Impact Assessment (LCIA) to quantify changes in global warming, resource use, and other midpoint indicators.

Table 1. VoD Life-Cycle Stages and GHG Intensity Sources

VoD stage	Inventory source	Typical GHG / energy intensity (placeholder)
Content production	Secondary LCA datasets [3]	Large-budget feature film ≈ 400–1100 t CO_2-eq per film
Content delivery – Data centres	Secondary LCA datasets [4]	Storing 100 GB y^{-1} ≈ 0.2 t CO_2-eq Storing a 5 GB HD movie y^{-1} ≈ 10 kg CO_2-eq
Content delivery – Data transfer	Secondary LCA datasets [5]	Downloading 1 GB ≈ 0.004 kWh ≈ 2 g CO_2-eq Downloading a 5 GB movie ≈ 0.020 kWh ≈ 10 g CO_2-eq
Content consumption – Android phone	**Primary power monitoring**	*2.76 Wh for 100 % brightness, 1440 p, volume 100 %* *2.22 Wh for 75 % brightness, 1080 p, volume 50 %*
Content consumption – Home router	**Primary power monitoring**	*5.99 Wh for router streaming 1440 p* *5.88 Wh for router streaming 1080 p* *5.84 Wh for router streaming 720 p*

Table 2. Behavioral Parameters and Experimental Setup

Variable type	Parameter	Levels / Units
Independent	Screen brightness	50 % · 70 % · 100 %
	Resolution	720 p · 1080 p · 1440 p
	Platform	YouTube · Netflix . Amazon Prime
	Audio volume	50 % · 70 % · 100 %
	Battery-saver mode	On · Off
	Streaming-run length	15 min per scenario
	Stabilisation pause	5 min before each run
Dependent	Device (Phone / TV) energy use	Wh per run (scaled to Wh h^{-1})
	Router energy	Wh per run

Challenges

- **Limited data transparency** – Accurate data on energy use, hardware materials, and emerging tech is scarce or non-public.
- **Rapid system change** – ICT evolves quickly, with tech driven by innovation rather than stable demand, complicating predictions.
- **Shared infrastructure** – Data centres, networks, and user devices serve multiple services simultaneously, making it hard to isolate streaming-related impacts.

Key Takeaways

- In one hour of YouTube playback, **phone power draw is driven mainly by screen brightness**, while router power draw is driven mainly by video resolution; other settings have minor effects.
- With all other settings at maximum, **dimming the phone screen from 100 % to 50 % cuts about 0.58 Wh (~21 %) per hour on the phone**, whereas lowering **resolution from 1440 p to 720 p cuts only 0.23 Wh (~8 %) on the phone**.
- Switching the phone from **a "max" profile** (100 % brightness, 1440 p, volume 100 %) to **a "typical" profile** (75 % brightness, 1080 p, volume 50 %) **reduces hourly use from 2.76 Wh to 2.22 Wh** (~20 %) on the phone.

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Reference:

1. Sandvine 2023; Cisco 2020
2. Istrate et al., 2023
3. Sustainable Production Alliance 2021
4. Stanford SAGE 2017 (CMU data)
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