AN AUGMENTED REALITY FRAMEWORK FOR MARKETING GREEN CHARCOAL: A CASE OF AMURU AND GULU CITY NORTHERN UGANDA.

BY

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Declaration

I, Aciro Gladys, hereby declare that this research report is my original work and has not been submitted to any institution of learning for any academic award or publication. All sources of information used in the report have been duly acknowledged.

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Approval

This is to certify that the dissertation entitled,

"An Augmented Reality Framework for Marketing Green Charcoal in Amuru District and Gulu City, Northern Uganda"

has been carried out by the student under my supervision. I hereby confirm that this is the student's original work and has been completed to the required academic standards.

Supervisors

1. Dr. Tabo Olok Geoffrey Signature Date August 7th 2026

2. Dr. Abudu Dan Signature Date August 7th 2026

ii

Dedication

This work is dedicated with deepest love and gratitude to:

My parents, to my beloved mother the late Mrs. Ayet Rose Achula whose memory continues to inspire and strengthen me every day. Your love, sacrifices and unwavering belief in me remain my guiding light. And to my father Mr. Achula Charles thank you for being my unwavering pillar of support, your financial sacrifice, steady guidance and the foundational role you played in shaping my education and personal growth have made this achievement possible, your belief in my potential has fueled my determination every step of the path.

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Table of Contents

Declaration i
Approval ii
Dedication iii
Acknowledgements iv
List of Tables viii
List of Figures ix
List of Abbreviations x
Abstract xi
Chapter one: Introduction 1
1.1 Background of the study 1
1.2 Statement of the problem 2
1.3 Main Objective 3
1.4 Specific Objective 3
1.5 Research Questions 3
1.6 Scope of the study 4
1.6.1 Geographical scope 4
1.6.2 AR-based Marketing framework Scope 5
1.7 Significance of the study 6
1.8 Research Contributions 6
Chapter Two: Literature Review 8
2.1 Introduction 8
2.2 Green Charcoal Technology and Adoption Challenges 8
2.3 Applications of AR and VR in Marketing 9
2.3.1 Retail and fashion 10
2.3.2 Automotive 11
2.3.3 Tourism and hospitality 12
2.3.4 Food and beverage 13
2.3.5 Education and training 14
2.4 Augmented Reality and Consumer Psychology 15
2.5 AR Technologies and Renewable Energy Marketing 16
2.6 Research Gaps and Justification for this Research 17
Chapter Three: Methodology 19
3.1 Introduction 19
3.2 Research Approach 19

3.3 Research Design. 19
3.4 Agile research methodology 19
3.5 Design science research (DSR) methodology 20
3.6 Justification for Choosing Design Science Research Methodology 21
3.7 Artefact Development using Unity AR Framework 23
3.7.1 The AR based Marketing framework Architecture 24
3.8 Description of the Designed Proposed AR framework 26
3.9 Data Collection 29
3.10 Sampling Technique 29
3.11 Data Analysis 30
3.12 Ethical Considerations 30
Chapter Four: Presentation of Results 32
4.1 Introduction 32
4.2 Demographic Profile of Respondents 32
4.3 Objective 1: To map out technology resources for green charcoal production and marketing 33
4.4 Objective 2: To design an Augmented reality-based framework for marketing green charcoal 35
4.5 Objective 3: To test the AR based framework in marketing green charcoal. 36
4.6 Objective 4: To evaluate the effectiveness of the Augmented Reality Framework 39
4.7 Visualization of Unity AR based marketing framework Outputs 39
Chapter Five: Discussion 44
5.1 Introduction 44
5.2 Objective 1: To map out technology resources for green charcoal production and marketing 44
5.3 Objective 2: To design an Augmented reality-based framework for marketing green charcoal 45
5.4 Objective 3: To test the AR based framework in marketing green charcoal. 46
5.5 Objective 4: To evaluate the effectiveness of the AR-based framework in promoting awareness and market access for green charcoal 47
Chapter Six: Conclusion, and Recommendation 49
6.1 Summary of Key Findings 49
6.2 Conclusion 49
6.3 Recommendation 51
6.4 Areas of Future Research 51
References 53
Appendices 57

Appendix I: Screen shots from field testing 57
Appendix II: Questionnaires 58
Appendix III: Key Informant Interview Guide 62
Appendix IV: Observation checklist for green charcoal production and marketing 64
Appendix V: Introduction Letter from the Faculty of Science 65
Appendix VI: Approval from GREC 66
Appendix VII: Source code 69

List of Tables

Table 3.1: Population Table 29
Table 3.2: Sample Table..... 29
Table 4.1: Demography of the respondents 32
Table 4.2: Knowledge on green charcoal production and usage 34
Table 4.3: Technology resources access 35
Table 4.4: Production and marketing of green charcoal 38

List of Figures

Figure 1.1: Map of the study area 5
Figure 2.1: Example of green charcoal products from agricultural waste. 8
Figure 2.2: Global AR and VR revenue streams in Marketing SB.Shinde et al, (2025) 10
Figure 3.1: Adoption of Design Science Research based on (Hevner et al.(2004a) 22
Figure 3.2: Proposed conceptual flow diagram of the proposed AR-based marketing framework 27
..... 28
Figure 3.3: Model of a typical working AR Framework for marketing Green Charcoal..... 28
Figure 4.1: Shows the mobile AR application install on a mobile device 40
Figure 4.2: Shows what happen upon launching the app and AR camera targeting an Image. 40
Figure 4.3: Shows AR Visualization of Green charcoal image in a real-world environment 41
Figure 4.4: Showing the interface on the production process of green charcoal. 41
Figure 4.5: Illustrating process of making green charcoal. 42
Figure 4.6: Powder after crushing process to produce green charcoal. 42
Figure 4.7: Illustrating the user testing session. 43

List of Abbreviations

Abbreviation	Definition
AR	Augmented Reality
Al	Artificial Intelligence
DSRM	Design Science Research Methodology
3D	Three Dimensional
2D	Two Dimensional
GHG	Greenhouse Gas
SDG	Sustainable Development Goal
EMKs	Earth Mound Kilns
VR	Virtual Reality
apps	Applications
NGO	Non-Governmental Organisation
DSR	Design Science Research
C#	C-sharp Object-oriented programming Language
SDKs	Software Development Kit
iOS	iPhone Operating System
fbx	Flimbox
png	Portable Network Graphics
UI	User Interface
GUREC	Gulu University Research Ethic Committee
SOPs	Standard Operating Procedures
N/A	Not Applicable
e.g.	for example,
IoT	Internet of Things
UPCHAIN	Unlocking the Potential of Green Charcoal Innovation to Mitigate Climate Change in Northern Uganda.
Briquette	Referring to Green Charcoal sometimes

Abstract

Despite 20 years of green charcoal initiatives in Northern Uganda, awareness and adoption remain low, traditional fuel use continues to drive deforestation, this study proposes an Augmented Reality-based marketing framework to boost green charcoal adoption, supporting sustainability and clean energy access, the study aimed to evaluate and test the AR-based marketing framework in promoting green charcoal awareness and adoption. The study explored the use of a Unity-based AR marketing framework to promote green charcoal adoption in Northern Uganda. High smartphone penetration and digital readiness among users supported AR implementation. The AR prototype effectively addressed key barriers such as limited awareness, product misconceptions, and poor marketing through immersive, multilingual simulations. It focuses on digital innovation to support sustainable energy use, particularly benefiting rural communities and aligning with sustainable development goals.

This study employs a Design Science Research Methodology (DSRM) to develop and evaluate an interactive AR-based marketing framework designed to promote awareness and adoption of green charcoal in Northern Uganda. The AR-based marketing framework, built using Unity 3D and AR Foundation, simulates the green charcoal production process through 3D models, and interactive educational content.

The study mapped the existing technological resources for green charcoal production and marketing in Gulu City and Amuru District and found that production largely relies on locally fabricated equipment, while marketing is predominantly conducted through word-of-mouth with limited use of digital platforms. Despite these limitations, high smartphone ownership (91%) and willingness to adopt digital marketing tools (80%) demonstrated strong potential for introducing AR-based solution. Guided by stakeholder requirements, a Unity-based AR mobile application was designed to provide interactive product information, production demonstrations, vendor locations, environmental benefits, and ordering services. Prototype testing showed that the application was easy to use, informative, and effective in increasing users' understanding and interest in green charcoal, although internet connectivity and ordering functionality required further improvement. Overall, the AR-based framework demonstrated significant potential to enhance public awareness, improve consumer engagement, strengthen producer-consumer communication, and expand market access for green charcoal, thereby supporting the adoption of sustainable energy solutions in Northern Uganda.

Chapter one: Introduction

1.1 Background of the study

Energy production and consumption are deeply intertwined with environmental sustainability. Nearly every form of energy generation, transportation, and usage carries environmental consequences such as greenhouse gas (GHG) emissions, air pollution, deforestation, and water contamination Riordan et al. (1999) . As the world transitions toward sustainable development, especially given climate change threats, the adoption of cleaner, naturally regenerative energy sources a global imperative. This transition aligns with Sustainable Development Goal 7 (SDG 7), which aims to ensure access to affordable, reliable, sustainable, and modern energy for all.

In Uganda, biomass accounts for over 90% of the national energy mix, primarily in the form of firewood and charcoal UBOS, (2021) Modern energy sources like electricity and petroleum derivatives contribute only marginally, with electricity accounting for about 1.1%, and other petroleum products such as diesel and kerosene contributing about 7.4% Gebru & Elofsson, (2023). This high reliance on biomass has led to higher levels of deforestation and environmental degradation. Uganda has lost approximately 63% of its forest cover over the past two decades due to unsustainable wood harvesting for charcoal, firewood, and land-use changes for agriculture and settlement Bamwesigye et al. (2020)

According to the Uganda National Household Survey UNHS, (2020), 73% of urban households use charcoal mainly as a cooking fuel, with over 40% of this charcoal from Northern Uganda. This high demand, further intensified by rapid urbanization and the refugee influx from neighbouring South Sudan, continues to place immense pressure on the country‟s forest resources. The resulting deforestation disrupts ecological functions such as rainfall regulation, soil fertility, and biodiversity conservation, making climate events like flooding and drought more frequent and severe. Despite its ecological costs, the charcoal industry plays a central role in Uganda‟s economy by providing income to many people across the value chain, from production and transportation to retail. Yet, the over-dependence on wood charcoal underscores an urgent need to identify and promote cleaner alternatives that integrate environmental sustainability with local economic development.

In this digital era, leveraging emerging technologies such as Augmented Reality (AR) can transform how green charcoal is marketed, distributed, and perceived. Augmented Reality is a technology that overlays computer-generated digital content such as 3D models, images,

videos, text, animations, and audio onto the real-world environment in real time through devices such as smartphones, tablets, or AR glasses creating interactive and immersive user experiences Playbook, (2020, p 5). With investments from major technology companies such as Apple, Meta, and Google, AR has increasingly become accessible through everyday smartphones, even in resource-constrained settings. AR offers significant potential in marketing, particularly in enhancing brand awareness, educating consumers, and showcasing product advantages in personalized and engaging ways Zhou et al. (2024). Globally, AR has been successfully used across diverse sectors such as health, tourism, construction, and retail to boost product visibility and user decision-making according to Gallardo et al. (2018). In Uganda, where smartphone penetration and internet connectivity are rising, with over 11.7 million internet users as of 2022, according to Thiede et al. (2022) mobile-enabled AR campaigns present an opportunity to promote green charcoal as a clean energy alternative.

Green charcoal, or biochar, has developed into a hopeful solution. Made from agricultural and forest residues such as maize cobs, leaves, coffee husks, and sugarcane bagasse, it is both environmentally friendly and economically inclusive. Women‟s groups in rural areas such as Amuru and Gulu have embraced green charcoal production as a livelihood strategy. The fuel burns more cleanly, emits fewer pollutants, and does not rely on cutting down trees. However, these community-based producers face significant marketing challenges. Their sales of products usually occur through informal word-of-mouth methods or small community gathering, which limits visibility and uptake beyond local markets.

This study proposes the development of an AR-based marketing to popularize green charcoal in Northern Uganda, particularly in Gulu and Amuru districts. The integration of digital innovation with sustainability aims to increase adoption, support local livelihoods, and contribute to Uganda‟s broader climate resilience and clean energy goals.

1.2 Statement of the problem

Despite the presence of green charcoal production initiatives for more than 20 years in Northern Uganda, public awareness and adoption remain very low. A preliminary survey at Cereleno Market in Gulu City revealed that only 1 in 10 respondents had knowledge of green charcoal, underscoring a substantial information and accessibility gap. At the same time, traditional charcoal and firewood use continues to be a major driver of deforestation and environmental degradation in the region, accounting for an estimated 51% of forest cover loss (Hajdu et al. (2016). This unsustainable trend is exacerbated by rapid population growth and

the influx of South Sudanese refugees, which further increases pressure on natural resources. Without timely intervention, the reliance on traditional biomass will continue to harm the environment, undermine climate resilience efforts, and limit access to clean energy alternatives. Green charcoal presents a viable, eco-friendly solution. However, its market reach and consumer engagement are constrained by limited visibility and ineffective marketing channels. This study seeks to bridge the awareness and adoption gap by designing and evaluating an AR-based marketing framework to promote green charcoal use in Gulu and Amuru. This supports climate change mitigation, improve energy access, and unlock the economic potential of sustainable biomass innovations.

1.3 Main Objective

To Assess and evaluate an augmented reality framework for marketing of green charcoal.

1.4 Specific Objective

i) To map out technology resources for green charcoal production and marketing.
ii) To design an augmented reality-based framework for marketing green charcoal.
iii) To test the AR based framework in marketing green charcoal.
iv) To evaluate the effectiveness of the AR-based framework in promoting awareness and market access for green charcoal.

1.5 Research Questions

1. How can an Augmented Reality (AR) framework improve the marketing, awareness, and market access of green charcoal in Gulu City and Amuru District?
2. What technological resources are currently available for green charcoal production and marketing in Gulu City and Amuru District?
3. What functional and user requirements should be incorporated into an Augmented Reality framework for marketing green charcoal?
4. How usable and acceptable is the developed Augmented Reality framework for marketing green charcoal among its intended users?
5. How effective is the Augmented Reality framework in improving awareness and market access for green charcoal?

1.6 Scope of the study

1.6.1Geographical scope

Northern Uganda occupies the northern part of the country, which is known to be among the most economic and geopolitical area of the country, Northern Uganda comprises of the districts of Amuru, Agago, Pader, Kitgum, Lira, Apac, Kole, Lamwo, Gulu and Nwoya however for the purpose of this study the district of interest in order to objectives of the study are Gulu, and Amuru**.** The climate around the area is tropical wet and dry season, the rainy season runs from late March to the end of November. The average rainfall was approximately 1,450mm annually (JICA, (2011a) The major economic activity in Gulu city is wholesale and retail trades, the construction industry, and non-agricultural household-based enterprises. Major sources of employment include commerce trade, industry and public services while the main economic activity in Amuru district is subsistence agriculture which is the backbone of the district economy, employing approximately 98% of the population, Arable land which make up to 90% of the total land area in the district making it very fertile, crops that are grown in the area includes, cotton, maize, millet, sorghum, sweet potatoes, cassava, beans, peas, sunflower and upland rice. Northern Uganda is a geopolitically and economically significant region of the country. It comprises several districts, including Amuru, Agago, Pader, Kitgum, Lira, Apac, Kole, Oyam, Abim, Dokolo Lamwo, Gulu, and Nwoya. However, for the purposes of this study, the geographical focus is limited to Gulu City and Amuru District **(Figure 1.1)**, selected due to their active involvement in green charcoal production, energy demand, and marketing challenges aligned with the study objectives. The region experiences a tropical wet and dry climate, with a rainy season that typically spans late March to the end of November. The average annual rainfall is approximately 1,450 mm according to JICA, (2011b), supporting both agricultural activities and biomass production. Gulu City is the largest urban centre in the region,with a diversified economy dominated by wholesale and retail trade, construction, and non-agricultural household-based enterprises. Employment is largely driven by commerce, industry, and public service sectors. In contrast, Amuru District remains predominantly rural, with subsistence agriculture serving as the backbone of the local economy. Agriculture employs nearly 98% of the population, with arable land comprising up to 90% of the total land area. Amuru plays a key role in supplying biomass fuels, including traditional and green charcoal, to urban markets such as Gulu.

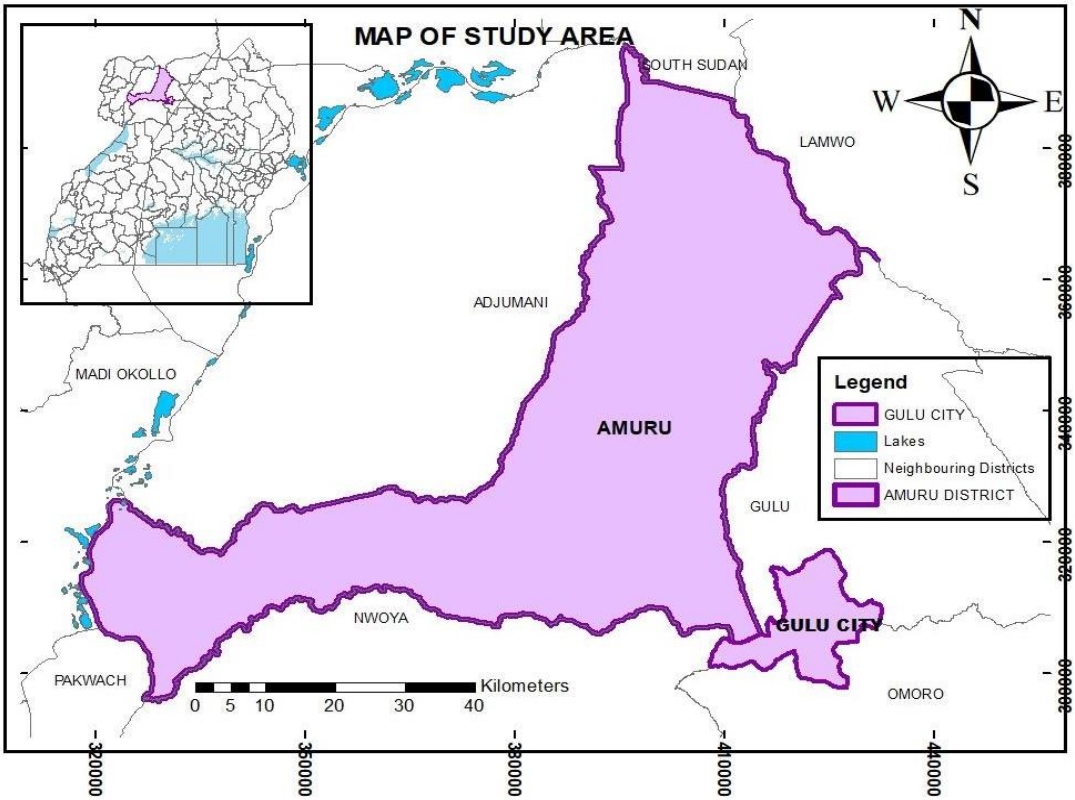


Figure 1.1**:** *Map of the study area*

1.6.2 AR-based Marketing framework Scope

The proposed framework will be an AR based application designed to enhance the visibility, accessibility, and marketing of green charcoal in Northern Uganda. It will utilize a smartphone camera feed to recognize commonly used energy products such as traditional wood charcoal. Upon recognition, the application overlay digital content to present green charcoal as a sustainable alternative. The key features of the framework include,

i) Displaying description of green charcoal and its environmental benefits.
ii) Suggesting nearest vendors or distribution points for purchasing green charcoal.
iii) Options for placing orders, delivery tracking, and pricing.
iv) Multimedia educational content on green charcoal production for interested users.

The application has been designed to operate on Android smartphones using Unity with AR Foundation and ARCore, ensuring compatibility with devices commonly available in the region. While the prototype may use simulated data during development, it is intended for

real-world application in marketing and consumer education. The research has been done over a one-year period, from May 2024 to May 2025, encompassing the following stages,

i) Data collection and green charcoal producers, vendors and users‟ engagement
ii) Design and prototyping
iii) Prototype testing (simulation and limited deployment)
iv) Evaluation and data analysis
v) Final reporting through a research dissertation

1.7 Significance of the study

This study is significant for several reasons. Firstly, it contributes to the growing body of knowledge on the application of Augmented Reality (AR) in promoting renewable energy products, particularly in the context of low-resource settings such as Northern Uganda. While AR has been widely applied in retail and education globally, its use in marketing clean energy solutions in Sub-Saharan Africa remains largely unexplored.

Secondly, the study has the potential to increase awareness and adoption of green charcoal as a sustainable energy alternative. With approximately 5.6 billion internet users globally (around 65% of the world's population) and 11.7 million internet users in Uganda, AR-enabled mobile technologies offer a scalable, cost-effective way to disseminate product information and influence consumer behavior.

Thirdly, the project aligns with and supports the achievement of multiple Sustainable Development Goals (SDGs), such as SDG 7 on ensuring access to affordable, reliable, sustainable, and modern energy for all, SDG 1 on ending poverty, by promoting green charcoal as an income-generating opportunity for rural entrepreneurs, especially women, and SDG 13 on taking urgent action to combat climate change, by reducing reliance on traditional wood charcoal and associated deforestation.

1.8 Research Contributions

The key contribution of this research is the development of a mobile AR application aimed at promoting the production and use of green charcoal in Gulu and Amuru districts. The AR framework has been designed to serve as a knowledge-sharing and marketing platform, enabling users to,

i) Learn about the environmental and economic benefits of green charcoal,
ii) Access purchasing and production information,

iii) Visualize product use through immersive AR experiences.

Through this application, the study bridges a critical information and visibility gap that has hindered the growth of green charcoal markets in Northern Uganda. It also serves as a practical demonstration of how digital innovation, specifically AR can be harnessed to address clean energy challenges in rural and peri-urban communities.

Chapter Two: Literature Review

2.1 Introduction

This chapter presents a review of existing literature on the application of Augmented Reality (AR) in various sectors, especially in marketing, and explores the production, marketing, and adoption challenges of green charcoal as a renewable energy source. The aim is to understand how AR can be leveraged to popularize green charcoal in Northern Uganda and identify existing research gaps that this study intends to address.

2.2 Green Charcoal Technology and Adoption Challenges

Green charcoal **(Figure2.1)**, also known as biochar, briquette or eco-charcoal, is produced from agricultural residues such as maize cobs, sugarcane bagasse, coffee husks, and sawdust through pyrolysis. It provides a sustainable and clean alternative to traditional wood-based charcoal, which contributes significantly to deforestation and greenhouse gas emissions (Sharma et al. (2015), (Bailis, (2009) In Uganda, green charcoal is seen as a viable energy solution for both domestic and industrial use. The green charcoal value chain includes raw material sourcing, production, transportation, storage, marketing, and end-use consumption (Yustas et al. (2022). However, adoption is limited due to encounters like as limited or no awareness, inadequate marketing channels, limited distribution networks, high production costs, and consumer preference for conventional charcoal (Bailis, (2009).



Figure 2.1: *Example of green charcoal products from agricultural waste.*

Traditional charcoal remains the dominant household energy source in Uganda, particularly in urban centres. Emissions from earth-mound kilns (EMKs), the utmost extensively used technique are significantly higher compared to improved kilns. Bailis, (2009) indicate that EMK emissions range from 0.14 to 0.84 tCO_2e per ton of charcoal, whereas improved kilns produce emissions between 0.40 and 0.82 tCO_2e per ton. Despite this, improved kilns remain underutilized due to lack of awareness, initial cost, and limited policy enforcement.

The distribution and marketing of green charcoal in Northern Uganda are largely informal. In areas such as Pabbo and Atiak in Amuru district, consumers are primarily institutions and restaurants. The scarcity of established retail networks further hinders consumer access. Moreover, green charcoal producers often rely on word-of-mouth promotion, limiting outreach and market growth. There is an urgent need to enhance marketing efforts and public awareness through innovative channels. Green charcoal presents opportunity not only for protecting environment but also for employment and income generation, especially among youth and women-led groups engaged in production.

2.3 Applications of AR and VR in Marketing

Augmented Reality (AR) and Virtual Reality (VR) technologies are transforming the marketing landscape by enabling brands to deliver immersive and interactive customer experiences. AR overlays digital content onto the real-world using smartphones or smart glasses, while VR creates entirely simulated environments typically accessed through headsets. These technologies foster emotional engagement, enhance information retention, and provide consumers with a unique experiential journey that traditional marketing channels cannot offer. As global digital adoption increases, AR and VR are becoming vital tools for brands to differentiate themselves in competitive markets.

In low-resource environments such as Uganda, AR has more potential than VR due to the widespread availability of smartphones and the relatively low costs associated with AR development and deployment. Research by Hakansson & Hakansson, (2018) underscores AR‟s appropriateness for developing nations, in which it can bridge gaps in access to information, promote localized content, and engage rural populations through mobile-based applications. AR enables consumers to visualize products in their environment, interact with promotional content remotely, and make sound decisions without the necessity for physical store visits.

The adoption of AR and VR in marketing has expanded rapidly across multiple sectors, such as retail, automotive, tourism, food and beverage, and education, with large market values **(Figure2.2)**. Their applications range from product visualization and virtual try-ons to immersive brand storytelling and hands-on training simulations. These experiences not only influence purchase intentions but also deepen brand loyalty by creating memorable and personalized interactions. Companies are increasingly investing in these technologies to capture digital-native consumers and enhance omnichannel strategies.

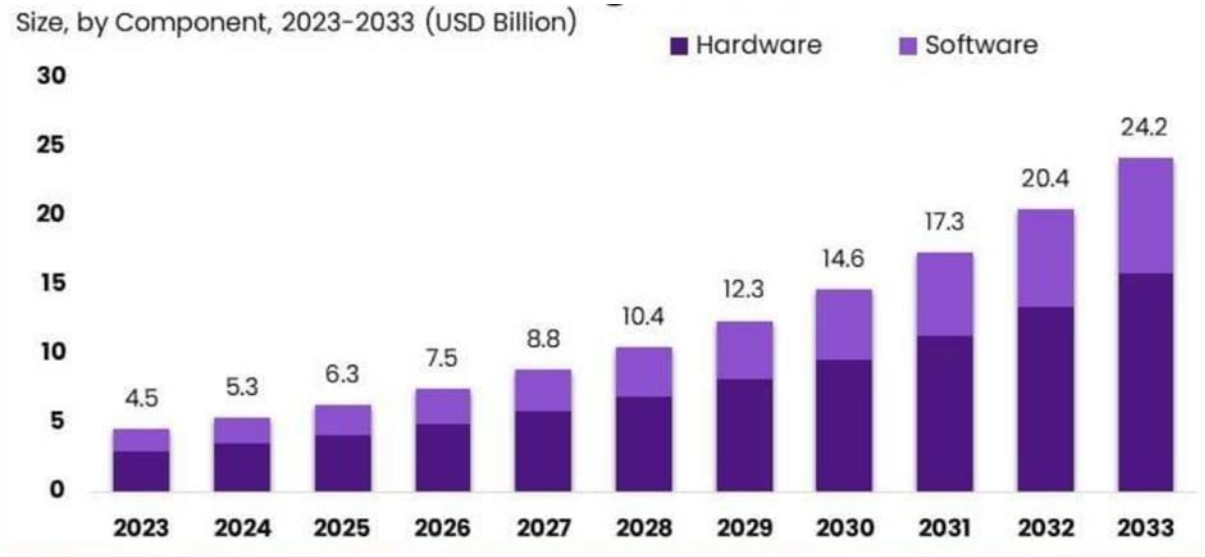


Figure 2.2: *Global AR and VR revenue streams in Marketing SB.Shinde et al, (2025)*

Despite the promising benefits, challenges remain, particularly in scaling these technologies in rural and peri-urban areas. Issues such as internet access, device compatibility, and digital literacy can limit the reach of AR and VR marketing campaigns. However, mobile-first AR applications and offline-compatible solutions are emerging as viable pathways for broader adoption in settings like Uganda. As such, the strategic integration of AR and VR in marketing embraces vast potential for both developed and developing markets.

2.3.1 Retail and fashion

AR and VR have revolutionized the retail and fashion sectors by providing consumers with tools to try products virtually before purchasing. In fashion, for example, AR-based applications such as Sephora‟s Virtual Artist allow users to test makeup products using facial recognition, while home décor apps like IKEA Place enable consumers to visualize furniture within their living spaces. These innovations reduce purchase uncertainty and empower customers with greater confidence in their buying decisions. By eliminating the need for

physical interaction, virtual try-ons have proven especially useful in the era of contactless shopping.

In the fashion industry, AR helps address the issue of high product return rates, a common challenge in online shopping. By allowing consumers to see how garments fit or look in real time, AR significantly narrows the gap between digital browsing and in-store experience. Research by Javornik, (2016) highlights the impact of AR on consumer engagement, noting increased emotional involvement and a stronger sense of product ownership. This, in turn, translates into higher conversion rates and brand loyalty.

Retailers are also leveraging VR to build immersive virtual stores that replicate the layout and ambiance of physical retail spaces. Though more hardware-intensive than AR, VR retail environments can enhance brand storytelling and create rich shopping experiences. For example, luxury brands have used VR to provide virtual tours of fashion shows or flagship stores, thereby elevating their exclusivity and appeal. However, due to cost and access limitations, VR adoption remains limited in regions with low technological infrastructure.

In Uganda and similar contexts, mobile AR is better positioned to disrupt the retail space. With smartphone penetration steadily rising, AR applications that offer try-before-you-buy experiences are increasingly feasible. These tools can be localized for fashion trends, fabrics, and design preferences unique to specific communities. Therefore, AR provides a low-cost yet powerful platform to extend retail experiences to underserved populations, ultimately fostering digital inclusion in commerce.

2.3.2 Automotive

The automotive industry has embraced AR and VR technologies to enhance customer experience through immersive product demonstrations and virtual showrooms. With AR, potential buyers can explore car interiors, exteriors, and features in detail using mobile apps. BMW, for instance, developed the **BMW i Visualiser**, which allows users to view and interact with life-sized 3D models of vehicles in their real environment. Such tools empower consumers to evaluate car aesthetics and features from the comfort of their homes, facilitating better-informed decisions.

Virtual reality takes this a step further by enabling users to simulate driving experiences or interact with different models in virtual showrooms. Automotive companies use VR in both sales and after-sales services, including test drives, maintenance tutorials, and product

training. According to Rauschnabel et al. (2024a) these experiences increase consumer satisfaction and shorten the purchase decision cycle by reducing the reliance on physical showrooms. VR also plays a significant role in product development and staff training within automotive companies, making it a multi-functional tool.

From a marketing standpoint, AR and VR also help create strong brand experiences and emotional connections. By offering consumers a personalized and interactive journey through the brand‟s product line, companies are better able to communicate value propositions and stand out in a competitive market. This form of experiential marketing aligns well with the preferences of digitally savvy and experience-driven consumers, especially in urban settings.

While high-end VR installations may not be feasible in Uganda, mobile-based AR solutions can still offer significant value in automotive marketing. Local dealerships could use AR apps to showcase models that are not available in stock or to promote vehicle features during outreach campaigns in rural areas. As mobile device capabilities improve, AR will likely become an essential tool for vehicle marketing, expanding consumer access and reducing marketing costs for dealerships

2.3.3 Tourism and hospitality

AR and VR are powerful storytelling tools in the tourism and hospitality sectors. They allow potential visitors to preview destinations, explore hotel rooms, or experience cultural attractions virtually. These immersive previews not only stimulate interest but also reduce travel anxiety, especially among first-time or international travellers. Virtual reality applications such as Google Earth VR and AR city guides bring historical sites, museums, and natural landmarks to life, thereby enhancing the travel planning process.

In cultural tourism, AR enhances physical visits by layering digital content such as historical facts, interactive maps, or 3D reconstructions onto real-world attractions. Museums and heritage sites use AR apps to offer guided tours or restore ruins virtually, enabling deeper visitor engagement. (Zhu & Wang, (2022) emphasize the role of AR in preserving intangible cultural heritage, especially when integrated with mobile storytelling to reach younger and tech-savvy audiences.

The hospitality industry also benefits from VR and AR by offering virtual hotel walkthroughs, allowing guests to explore rooms, amenities, and surrounding areas before booking. This enhances transparency and trust, particularly in online bookings. VR also

supports staff training in customer service scenarios, improving quality assurance and operational efficiency. For customers, the ability to "experience before booking" increases satisfaction and lowers the likelihood of disappointment upon arrival.

For Uganda‟s tourism sector, especially in promoting wildlife, cultural heritage, and adventure tourism, AR can serve as a low-cost promotional tool. Virtual previews of safari parks or cultural events can be shared via mobile apps or social media, drawing in both domestic and

international tourists. Given the country‟s rich natural and cultural resources, AR offers an opportunity to modernize tourism marketing and improve outreach to rural attractions that are often overlooked.

2.3.4 Food and beverage

In the food and beverage industry, AR is being creatively applied to packaging, advertisements, and customer engagement. Brands use AR to deliver interactive content through product packaging, allowing consumers to scan labels and unlock games, nutritional information, or promotional videos. This approach transforms a static product into a dynamic experience, increasing the likelihood of brand recall and loyalty. Pepsi‟s “Unbelievable” AR campaign is a notable example of engaging storytelling delivered through augmented reality.

AR applications also promote brand narratives by blending visual storytelling with gamification. For example, scanning a cereal box might trigger a mini-game or an animated story involving the brand mascot. This approach is particularly effective in targeting younger audiences and creating emotional connections. According to Kang et al. (2018) AR packaging campaigns have a positive impact on customer attitudes and purchase intentions, especially when aligned with entertaining or educational content.

VR is less commonly used in food marketing but has been adopted by select premium brands to offer immersive farm-to-table experiences or behind-the-scenes production tours. These narratives help position the brand as transparent and socially responsible, attributes increasingly valued by consumers. VR can also be used at exhibitions or pop-up events to offer virtual tastings or experiential storytelling for product launches.

In Uganda, AR could be used to promote local agro-based products such as green charcoal, coffee, or fruit juices. Through simple mobile apps, rural entrepreneurs could embed brand stories, usage tips, or even nutritional education into their packaging. This adds value to the

product and supports informal food sector marketing. Additionally, NGOs and public health agencies could adopt AR to disseminate food safety information and dietary guidelines in a visually engaging format, improving nutrition awareness in low-literacy populations.

2.3.5 Education and training:

AR and VR have become integral tools in education and professional training, offering immersive, context-rich environments that enhance learning outcomes. AR provides learners with an opportunity for visualizing complex ideas and interacting with 3D models, and receive real-time feedback. In medical training, for example, AR applications enable students to explore anatomical models or practice surgical procedures in a risk-free setting. This makes learning more efficient, engaging, and applicable to real-world scenarios.

VR offers fully simulated environments ideal for skill-based training in fields like aviation, engineering, or emergency response. Learners can perform procedures, handle virtual equipment, and engage in scenario-based exercises. According to Akcayır & Akcayır, (2017) AR and VR contribute to deeper understanding, higher retention, and increased learner motivation, particularly in STEM fields. These technologies also allow remote training, addressing geographic and infrastructural barriers.

Industry training also benefits from AR and VR, especially for roles requiring spatial awareness or complex procedures. For instance, factory workers can receive just-in-time training through AR wearables that guide them step-by-step. In aviation, VR flight simulators reduce training costs while maintaining high safety standards. These applications also extend to soft skills training, such as conflict resolution or customer service simulations, enhancing human-cantered learning approaches.

In Uganda, AR could support vocational training in agriculture, construction, or public health, particularly where hands-on experience is constrained. Mobile AR tools could simulate irrigation setups, pest control methods, or hygiene practices, facilitating learning in remote areas. Education ministries and NGOs can leverage AR to modernize curriculum delivery, especially under the constraints of limited teaching aids or classroom resources. This democratization of experiential learning can bridge rural-urban education gaps and prepare learners for future digital economies

2.4 Augmented Reality and Consumer Psychology

Augmented Reality (AR) has drawn growing academic attention, not only for its technical features but also for its psychological effects on consumers. One of its most compelling features is the ability to simulate "local presence" a psychological phenomenon in which users feel as though a virtual product is physically co-located with them. This spatial illusion creates emotional intimacy with the brand, heightening the consumer‟s sense of connection and engagement. The sense of realism and co-presence fostered by AR applications is not merely aesthetic; it has significant consequences for marketing outcomes, particularly in terms of emotional attachment, brand trust, and loyalty.

According to Rauschnabel et al. (2024b) provide empirical evidence that AR technologies enhance perceived closeness between users and products, which in turn contributes to "brand love." Through a series of experimental studies, the authors demonstrate that interactive AR experiences generate stronger affective responses than traditional advertising methods. For instance, users of the Mercedes-Benz AR app, which allows potential buyers to visualize and explore vehicles in their environment, reported significantly higher levels of brand proximity and attachment. This heightened psychological engagement led to greater interest in the product and improved brand recall, especially among first-time users.

Similarly, the Sephora Virtual Artist app offers users an AR-powered makeup trial that not only improves product fit confidence but also strengthens emotional ties to the brand. Users expressed increased loyalty and a deeper emotional connection, particularly when interacting with brands they were already familiar with. The personalisation and interactivity afforded by AR were key factors in this shift. This aligns with broader consumer psychology theories that emphasize the role of immersion, control, and sensory feedback in deepening user-brand relationships. These emotional connections translate into more favourable brand evaluations and greater willingness to adopt new products.

The results are highly relevant to emerging markets, including Uganda, where mobile AR could be a powerful tool for promoting socially relevant products like green charcoal. The psychological mechanisms observed in global case studies may apply equally well in these contexts, especially when AR content is culturally adapted and contextually relevant. For example, an AR campaign that allows users in Northern Uganda to visualize the environmental and health benefits of green charcoal at home could enhance not only consciousness but also sensitive character. This emotional framing, combined with digital

interactivity, could accelerate behavioural change and adoption in societies customarily underrepresented by mainstream advertising.

AR is not just a technological enhancement. It is a medium that reshapes consumer psychology. By offering realism, interactivity, and a sense of presence, AR prompts expressive replies which stimulus buyer attitudes and decisions. As such, join in purchaser mind-set principles into AR marketing strategies can be especially effective for introducing sustainable innovations like green charcoal in contexts where education, trust, and emotional engagement are critical to behavioural change.

2.5 AR Technologies and Renewable Energy Marketing

Digital technologies are playing a transformative role in shaping how renewable energy products are marketed, especially in regions where public awareness and consumer trust are still evolving. Augmented Reality (AR) stands out of all these technologies for its unique capability to visualize abstract or unfamiliar concept in a user-friendly and engaging way. By overlaying digital content onto the real world, AR helps consumers better understand how renewable energy products work, what their benefits are, and how they integrate into daily life. This is particularly relevant for emerging solutions such as green charcoal, solar kits, or biogas systems, which may be unfamiliar to many end-users.

One of the most compelling uses of AR in renewable energy marketing is its capacity to simulate production processes. For example, an AR application could demonstrate how green charcoal is made from biomass sourcing to carbonization and packaging.

Such visualizations can educate consumers on the environmental benefits of cleaner energy options and support discerns them from traditional biomass products like firewood or regular charcoal. By transforming complex technical content into interactive experiences, AR lowers cognitive barriers and enhances user engagement with sustainability narratives.

Beyond education, AR can also serve practical functions by delivering purchasing, usage, and delivery information directly through mobile interfaces. Users can scan packaging or promotional posters to access AR-enhanced content, including how-to videos, carbon savings estimates, or real-time order tracking. This form of interactive marketing enhances convenience and transparency key components in building consumer confidence and encouraging product adoption. In low-income settings, where access to energy alternatives

may still be fragmented, such technology-driven communication strategies can support overcoming data irregularity while building market linkages.

According to Zainab Efe Egieya et al. (2023) highlight the broader role that AR and digital technologies can play in transforming marketing approaches across sectors including energy, when integrated with strong HR strategies and digital upskilling. Their study argues that digital marketing effectiveness is amplified when organizational readiness and human capital are adequately developed. For the renewable energy sector, this implies that investments in digital innovation must be complemented by training programs for field staff, community agents, and entrepreneurs who interact directly with consumers. Doing so ensures that the human element of marketing keeps pace with technological advances.

Despite its potential, the adoption of AR in renewable energy marketing is not without challenges. High initial implementation costs limited local expertise in content development, and difficulties in scaling solutions across rural regions can impede broader deployment. These barriers are particularly pronounced in low-resource settings such as Uganda, where infrastructure and investment in digital tools may be limited. Nevertheless, mobile-first AR solutions and partnerships with local innovators offer promising pathways for overcoming these constraints. By strategically leveraging AR within broader digital marketing ecosystems, organizations can improve consumer understanding, promote adoption, and support the growth of sustainable energy markets.

2.6 Research Gaps and Justification for this Research

Despite the growing body of research on Augmented Reality (AR) in marketing, significant gaps remain in its application to renewable energy promotion, particularly in low-income regions.

Much of the existing literature has focused on sectors such as retail, automotive, and tourism, where AR is used to enhance product visualization and consumer engagement. While these studies have demonstrated that AR can foster emotional connections and influence purchase decisions, very few have examined how such technology can be adapted to the unique challenges of energy marketing in sub-Saharan Africa. This lack of attention is particularly concerning given the global push for sustainable energy transitions and the critical role of public engagement in driving clean energy adoption.

One of the key gaps is the absence of localized AR based marketing framework tailored to the Ugandan context, where traditional biomass fuels such as firewood and charcoal dominate household energy use. While green charcoal has emerged as a cleaner alternative, its uptake remains low, partly due to limited awareness and scepticism among consumers. Existing AR studies do not consider these behavioural and cultural barriers, nor do they address the infrastructural and digital divides that affect how information is accessed in rural and peri-urban communities. Consequently, much of the knowledge generated in high-income settings is not easily transferable to Uganda‟s energy landscape.

Additionally, no known studies have attempted to design, test, or simulate AR-based marketing framework for promoting green charcoal in Northern Uganda. This is a critical oversight, as the region continues to face environmental degradation from unsustainable charcoal practices and lacks sufficient investment in consumer education around cleaner alternatives. Most current outreach strategies rely on static materials such as posters or verbal communication, which may not effectively capture attention or convey the benefits of renewable charcoal. The use of interactive AR tools could potentially transform these approaches by making information more accessible, engaging, and memorable yet this potential remains unexplored in both academic and practical terms.

This study seeks to address these gaps by developing and evaluating an AR-driven marketing framework for green charcoal in two districts: Gulu and Amuru. The research will explore how AR can increase consumer awareness, drive emotional engagement, and ultimately support the adoption of clean energy solutions in underserved regions. By focusing on localized content and mobile-compatible delivery, the project will consider both technological feasibility and user accessibility. In doing so, it will contribute empirical insights into the effectiveness of AR in low-income energy markets, where digital innovation must be both scalable and socially relevant.

The study offers evidence-based recommendations for policymakers, NGOs, and entrepreneurs working in energy access and sustainability. These insights not only inform grassroots innovation strategies but also support national energy policy efforts to transition from traditional biomass to modern, cleaner alternatives. By filling a critical gap in both academic literature and applied practice, this research will help pave the way for inclusive digital marketing models that can catalyse behavioural change and accelerate energy transitions in vulnerable regions

Chapter Three: Methodology

3.1 Introduction

This chapter presents the methodology adopted in this study. It describes the research approach, research design, artefact development process, data collection methods, sampling procedures, data analysis techniques, and ethical considerations. It also explains why Design Science Research (DSR) was selected over Agile software development as the most suitable methodology for developing and evaluating the proposed Augmented Reality framework

3.2 Research Approach

In research design, adopting an appropriate research approach is essential for the success of a research study in any study. A research approach is a method that helps to answer the research questions appropriately Saunders, Lewi and Thornhill (2019). (Saunders et al., 2019b), stated that "the main research strategies are experiments, survey, case study, action research, grounded theory, ethnography, and archival research, and these strategies may be used in combination in the same research project." Houser defined a research approach as a thorough examination of literature review, case study, interviews, observations, experiments, surveys, among others.

3.3 Research Design.

This section discussed Agile and Design Science research methodologies. Several research methodologies can be adopted while developing an augmented reality framework. However, it is essential to assert that the suitability of each research methodology varies from one research study to another. Agile and Design Science Research methodologies were compared before selecting Design Science Research Methodology as the most appropriate methodology for this study.

3.4 Agile research methodology

According to Ribeiro & Domingues, (2018a), the Agile software development methodology emphasizes an iterative and incremental development of software, allowing features and requirements to evolve and the functions performed by cross-functional, collaborative, and self-organized teams (Ribeiro & Domingues, 2018b) and (Dingsøyr & Lassenius, 2016) stated that delivering services early to satisfy the customer is the primary goal of the Agile methodology. This methodology enables the development and delivery of services to customers at short regular intervals while integrating constant requirement changes during the

development stage - customers are involved in the development lifecycle(Dingsøyr & Lassenius, 2016) . The agile methodology consists of several methodologies that follow agility principles and practices. Beng Leau et al. (2012) indicated that Crystal methodologies, Dynamic software development method, Feature-driven development, Lean software development, Scrum, and Extreme programming are some Agile development methodologies. According to Beng Leau et al. (2012), the development life cycle in the Agile methodology is divided into increments or iterations where small parts of the software are developed through the conventional phases of development until the development is satisfactory. Beng Leau et al. (2012) identified the following practices used in Agile methodology to use the methodology successfully; face-to-face and frequent communication with other developers and customers, iteratively conducting requirements engineering, prioritizing requirements, prototyping, reviewing meetings, and acceptance testing. These practices are essential in an Agile environment because of the changing requirements and changing customer demand, which require adaptability and flexibility to assure that the product adheres to the customers‟ requirements and helps improve the development of the software.(Moniruzzaman et al.(2013) argued that the benefit of Agile methodology is that changes in the software requirements (additional features) can be included during the development lifecycle. Moniruzzaman et al. (2013) also stated that Agile teams consist of multi-skilled individuals with the expertise to understand the initial requirements and incorporate any requirements changes during the development lifecycle of the software, thus enabling timely delivery of the software. Beng Leau et al. (2012) argued that it is essential for developers in Agile to polish their interpersonal skills and basic business knowledge as this will enable them to deliver a valuable service to the customer.

3.5 Design science research (DSR) methodology

This looks at following a rigorous procedure of designing artefacts that can solve practical problems, make research contributions, evaluate the designs, and provide results to appropriate audiences. These artefacts can be models, methods, constructs, social innovations, or instantiations developed following the design science research cycle developed by Hevner, March, Park nd Ram, (2004). According to Alan, (2007), pragmatism‟s philosophy is associated with DSR methodology as it attempts to close the gap between science and practical action. Hevner et al. (2004b) further argue that the design science method has contributed to producing innovations that help define ideas, technical capabilities, and products through which the analysis, design, implementation, management, and use of

information systems can be effectively used and efficiently achieved. Design science is credited for its effectiveness in closing the relevancy gap or solving practical problems that over time affected academic research negatively in the management of information systems by creating artefacts that are successful in directing the implementation of Information systems projects.

Peffers et al. (2007) states that the "relevance cycle bridges the contextual environment of the research project with the design science activities. Hevner et al. (2004b) further states that the rigor cycle connects the design science activities with the knowledge base of scientific foundations, experience, and expertise that informs the research project; and the central design cycle iterates between the core activities of building and evaluating the design artefacts and processes of the research." Hevner also emphasized that these three-cycle model must be present and identifiable in a design science research project. According to Hevner et al. (2004a), DSR is a problem-solving methodology that "seeks to extend the boundaries of human and organizational capabilities" through "building and evaluation of artefacts designed to meet the identified business needs." These artefacts are the products of design science research categorized into four types: constructs, models, methods, and implementations or instantiations . In the context of this research, the artefact is the Augmented reality application to promote the use and production of green charcoal. Therefore, this research intends to adopt the DSR by (Hevner et al. 2004a).

3.6 Justification for Choosing Design Science Research Methodology

This study adopts a Design Science Research (DSR) methodology supported by a mixed-methods approach. Qualitative data were used to elicit system requirements from stakeholders, while quantitative data were used to evaluate the usability, usefulness, and acceptance of the developed AR marketing framework.

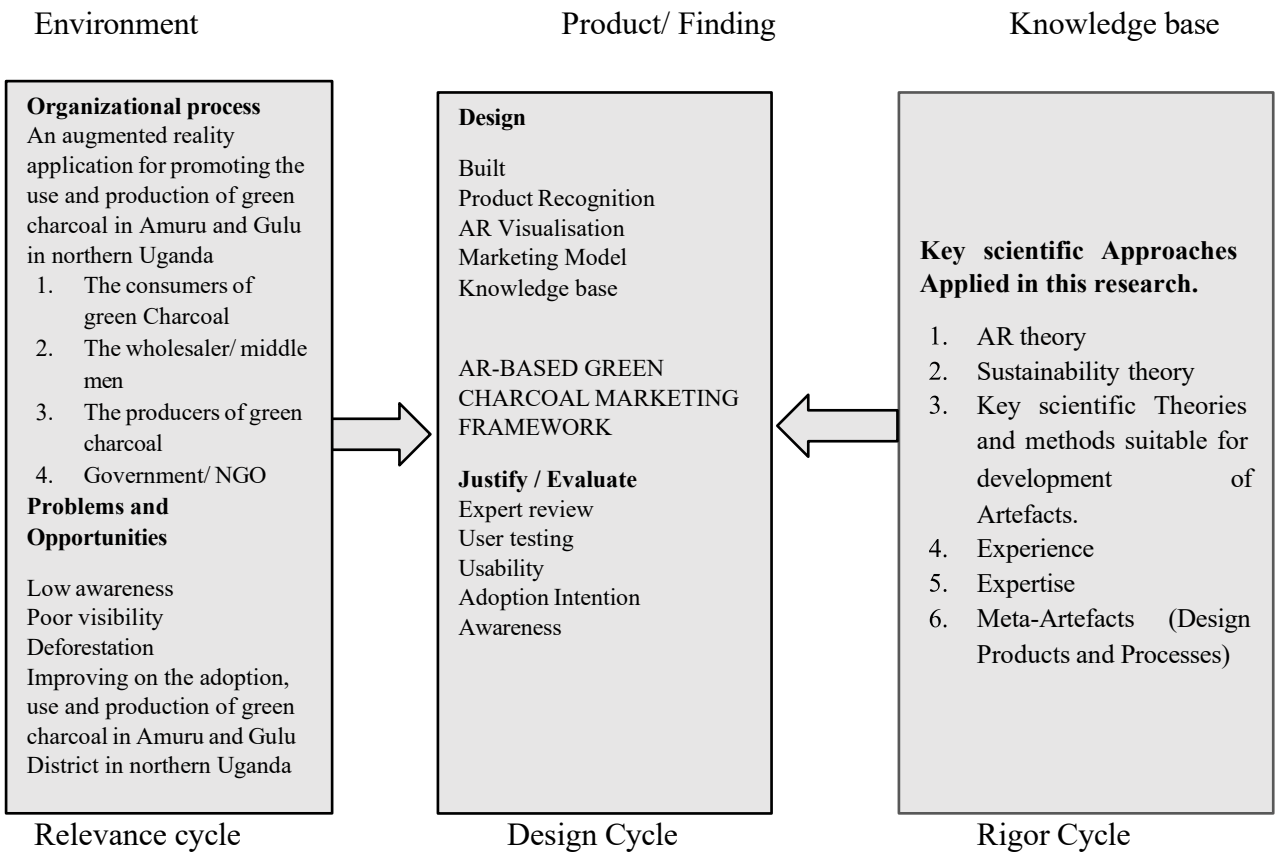


Figure 3.1: *Adoption of Design Science Research based on (Hevner et al.(2004a)*

Figure 3.1 illustrates the three-cycle model of Design Science Research. The relevance cycle captures the problem environment,

1. The key people involved in executing that process of interest
   - i The consumers of green Charcoal
   - ii The wholesaler/ middle men
   - iii The producers of green charcoal
2. the problems and opportunities that this research is concerned with
   - i improving on the adoption, use and production of green charcoal in Amuru and Gulu District in northern Uganda.

The design cycle focuses on artefact development and evaluation,

i. Designing an augmented reality application to promote the use and production of green charcoal in Amuru and Gulu city northern Uganda

The rigor cycle links the research to existing scientific knowledge the study of interest in this research intends to improve which is the adoption, use and production of green charcoal in Amuru and Gulu city in northern Uganda

i. where the Analysis and evaluation of the AR based marketing framework is done using structured walkthrough with expert in green charcoal production and use in the area of Amuru and Gulu in northern Uganda

3.7 Artefact Development using Unity AR Framework

The focus of this study was the development and empirical evaluation of an AR marketing tool (referred to as the artefact) Hevner (et al., 2004a)), created to address challenges in consumer engagement, awareness, and adoption of renewable energy products. Given the specific problem of low awareness and uptake of green charcoal in low-income regions like Northern Uganda, Design Science Research (DSR) enables structured artefact creation, contextual testing, and refinement based on theoretical and empirical feedback Peffers et al. (2007). The proposed AR based marketing framework was developed using Unity 3D, integrated with AR Foundation, which supports cross-platform deployment for both Android and iOS devices. The design logic of the AR application aligns with user-centered interaction principles and is guided by a system flow diagram **(see Figure3.2 and Figure 3.4)**. The core functionality begins with a user activating a button labeled "Production of Green Charcoal," which triggers the device‟s camera to search for a predefined marker or target image. Upon detecting the target, the application renders an interactive 3D model of the green charcoal production process, accompanied by multimedia content such as educational voiceovers, on-screen text, and interactive hotspots.

Key features of the artefact include target-based AR rendering (using image recognition and tracking), 3D models simulating production techniques, context-aware messaging on environmental and economic benefits, and multilingual support to ensure inclusivity for local communities in Uganda. This simulation-based approach enables users to visualize the otherwise hidden or unfamiliar production process of green charcoal, which enhances relatability, awareness, and potential adoption.

Prototype development

The development of the AR-based marketing framework was conducted using Unity 3D, a cross-platform game engine widely adopted for interactive 3D and AR/VR applications. Unity was selected due to its flexibility, extensive asset store, support for C# scripting, and compatibility with multiple AR SDKs. The Unity AR Foundation framework was integrated to enable marker-based image tracking and seamless deployment across both Android and iOS platforms. AR Foundation provides a unified API for working with *ARKit (iOS)* and

ARCore (Android), ensuring cross-device consistency in user experiences Deshpande, MVJ (2019).

For image detection, the application employed Unity's *ARTrackedImageManager*, which monitors the environmenThe left block of the figure representst for pre-defined image targets. These image targets were designed and optimized using Vuforia‟s Model Target Generator and Unity‟s XR Toolkit, allowing the app to recognize printed markers or product labels associated with green charcoal. When a target is detected, Unity‟s Scene Manager renders an overlay of a 3D model and text content explaining the green charcoal production process, its benefits, and distribution channels.

The interactive content was created using Blender and Adobe Illustrator, where necessary, to model and animate the production environment. These assets were drawn into Unity by means of file formats (*.fbx* and *.png*) to support real-time rendering on mobile devices. Programming within the Unity engine was done in C#, the default scripting language for Unity. Tailored scripts were created to support functionalities such as camera activation, object tracking, user interface (UI) interactions, and data logging. For multilingual content delivery and accessibility, *TextMeshPro* and Unity's localization packages were used to render translations and narration. The voiceover instructions were recorded in both English and the local Luo dialect to accommodate diverse audiences. Audio integration was handled through Unity‟s *AudioSource* and *AudioClip* components (Deshpande, MVJ, (2019).

Application testing was performed on mid-range Android smartphones (Android 9 and above) and entry-level tablets to ensure compatibility with devices accessible to the intended rural and peri-urban user base. Logging functions were embedded in the application to track user interactions, duration of use, and scene transitions, which supported later phases of usability analysis.

3.7.1 The AR based Marketing framework Architecture

The framework is developed using a cross-platform architecture that integrates computer vision techniques with AR rendering technologies. The application comprises three core components:

Computer Vision Pipeline: A Python-based model is developed using the YOLOv8 (Ultralytics) framework for real-time detection of traditional charcoal.

AR Framework: The application is built in Unity 3D using AR Foundation, enabling compatibility with both ARCore (Android) and ARKit (iOS) platforms.

Model Integration: The trained detection model is deployed on mobile devices using Unity Sentis (or ONNX Runtime), allowing for efficient on-device inference without reliance on cloud processing.

Phase I: Dataset Preparation and Model Training

To enable accurate detection of traditional charcoal, a robust object detection model was developed through the following steps

Data Collection: A diverse dataset of high-quality images representing traditional charcoal was collected under varying environmental conditions, including indoor and outdoor settings, different lighting intensities, and varied backgrounds.

Annotation: The dataset was uploaded to Roboflow, where images were manually labeled using bounding box annotations to define the target class ("Charcoal").

Preprocessing and Augmentation: Data augmentation techniques such as Mosaic (combining multiple images) and MixUp were applied to improve the model‟s robustness in detecting charcoal across different scales, orientations, and occlusions.

Model Training: The annotated dataset was used to train the detection model using the Ultralytics YOLOv8 library in Python.

Model Export: The trained model weights (best.pt) were converted into ONNX format to ensure compatibility with Unity-based deployment.

Phase II: AR Application Development in Unity

Unity serves as the primary integration environment, combining the camera feed, object detection logic, and AR visualization components:

Real-Time Inference: The device camera feed is continuously captured and processed into tensor format. This tensor is passed to the inference engine (Unity Sentis), which executes the YOLO model on a frame-by-frame basis.

Coordinate Mapping: The 2D bounding box outputs from the detection model are translated into 3D world coordinates using raycasting techniques, ensuring accurate spatial placement of AR elements.

Augmentation Trigger: When charcoal is detected with a confidence score above a defined threshold (e.g., >0.7), the system activates AR content, including, 3D Model Rendering, a detailed 3D model of a green charcoal briquette is overlaid onto the detected object.

Informational Interface: Contextual AR panels are displayed to provide relevant product information.

Phase III: Content Strategy (Information Layer)

The AR content is designed to educate users and promote behavioral change by highlighting the advantages of green charcoal.

Overall, the selection of the tools and technologies was driven by their performance in mobile AR development, accessibility to local developers, and support for rapid iteration, key requirements for building sustainable digital solutions in resource-constrained environments like Northern Uganda.

3.8 Description of the Designed Proposed AR framework

The framework logic illustrated in **(Figure 3.2)** demonstrates the sequential interaction design. The application begins by initializing core application functions. The user is prompted to press a button labeled "Production of Green Charcoal," which activates the AR camera interface. The application then scans for a target image. If a valid image is detected, it triggers the rendering of an interactive AR scene that includes a 3D model of green charcoal and overlays multimedia content on its production process, benefits, and points of purchase. If the application fails to detect a target image, it loops back to continue scanning until a match is found. Once the interaction concludes, the application resets or allows the user to explore additional modules. Unity‟s *ARTrackedImageManager* and *ARSessionOrigin* are utilized to manage image recognition and scene rendering. This setup ensures a responsive, immersive, and context-aware simulation suitable for educational outreach and behavioral influence.

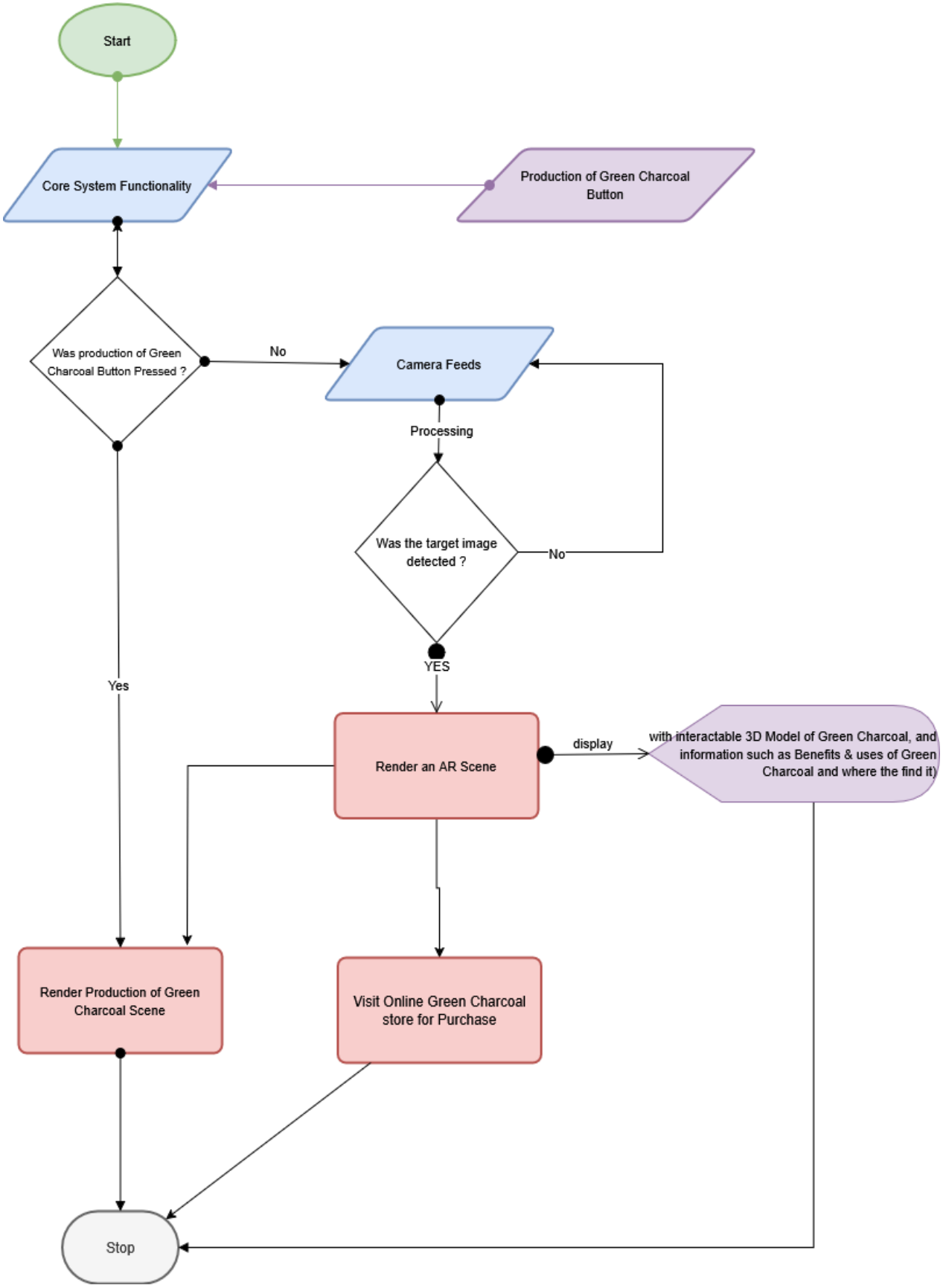


Figure 3.2: *Proposed conceptual flow diagram of the proposed AR-based marketing framework*



1. **Start the App & Point**
   App identifies the charcoal in the real



2. Automatic Recognition & Augmentation

App recognizes the charcoal and augments 3D image of charcoal and the benefits of green charcoal



3. Interactive Buttons

User interacts with on-screen buttons.



3a. Store Link

Redirects user to online store for Green Charcoal



3b. Video Scene

View the manufacturing process of green charcoal. Back button returns to AR Scene

4. Close App

App exit closes all augmented scenes and sessions

Figure 3.3: *Model of a typical working AR Framework for marketing Green Charcoal*

3.9 Data Collection

The Primary data were collected from households, green charcoal producers, vendors, environmental experts, and government officials through questionnaires, key informant interviews, and observation checklists.

Table 3.1: Population Table

Category	Population	Sample
Household	100	80
Producers	10	5
Vendors	20	10
Experts	10	5
Institutions	5	2

3.10 Sampling Technique

A quota sampling and purposive sampling techniques were used in the data collection process.

Table 3.2: Sample Table

Category	Population	Sample	Sampling Technique
Households	100	80	quota
Producers	10	5	Purposive
Vendors	20	10	Purposive
Experts	10	5	Purposive
Institutions	5	2	Purposive

Purposive sampling was employed to select green charcoal producers, vendors, environmental experts, government officials, and institutions because these participants possessed specialized knowledge and practical experience relevant to the study. According to Anderson, (2018) and Neetij & Bikash Thapa, (2004) the technique enabled the researcher to deliberately identify information-rich participants who could provide detailed insights into green charcoal production, marketing, policy implementation, and the practical application of the proposed Augmented Reality (AR) marketing framework. Since the study sought expert opinions on the design, implementation, and evaluation of the AR framework, randomly

selecting participants would not have guaranteed access to individuals with the required expertise. Therefore, purposive sampling ensured that data were collected from respondents who were most capable of addressing the research objectives and contributing to the development and evaluation of the artefact.

Ensuring Representation of Key Subgroups, Quota sampling allows the researcher to intentionally include specific subgroups within the population, such as households and consumers of green charcoal. Since these groups are crucial to the study, quota sampling ensures their adequate representation Alvi, (2016) .

Inconclusion quota sampling was used to select households (consumers) to ensure adequate representation of the target population and purposive sampling was used to select green charcoal producers, vendors, environmental experts, government officials, and supporting institutions because of their specialized knowledge and direct involvement in green charcoal production, marketing, and renewable energy initiatives.

3.11 Data Analysis

Data collected from the surveys and feedback forms were analyzed using R and RStudio, employing a mix of descriptive and inferential statistics. Descriptive statistics summarized the demographic profiles of participants and their general attitudes toward green charcoal. Cross-tabulations and chi-square tests were used to scrutinize relations amid demographic variables (e.g., age, education, urban/rural location) and their responses to the AR based marketing framework. A pre- and post-interaction comparison were used to assess changes in knowledge, attitudes, and behavioral intentions regarding green charcoal. Additionally, qualitative data from user feedback were thematically analyzed to identify usability challenges, the strengths of the framework, and contextual insights, which can inform future improvements to the application or its scalability.

3.12 Ethical Considerations

Ethical considerations are central to this research, particularly given its engagement with community participants and its deployment in rural and peri-urban contexts. Ethical approval was obtained from the Gulu University Research and Ethics Committee (GUREC) and administrative clearance from district offices in Gulu and Amuru. All participants will be informed of the research objectives, data use, participation procedures, and their right to withdraw at any time without consequences. Participation will be voluntary, and

confidentiality will be ensured by anonymizing all collected data. No personal identifiers will be linked to responses, and only aggregated findings will be reported.

Additionally, the research adhered to Uganda's Ministry of Health Standard Operating Procedures (SOPs) for community-based research. Respondents will be informed about potential risks and benefits of participating, including how their input contributes to developing tools that support clean energy awareness. Written or verbal informed consent will be obtained before any data collection, and data security protocols will be followed throughout the project. These measures uphold both ethical and professional standards, ensuring the dignity and safety of all participants involved in the study.

Chapter Four: Presentation of Results

4.1 Introduction

This chapter presents the findings from the development and evaluation of a Unity-based AR based marketing framework designed to promote the marketing and adoption of green charcoal in Gulu and Amuru districts, Northern Uganda. The findings are structured around the study's specific objectives as outlined in chapter one and aligned with the mixed-methods approach employed. Quantitative data obtained from questionnaire responses and qualitative feedback from user trials were to integrate respondents who had ever interacted with buying or selling products via mobile application to examine green charcoal awareness, production, market access, technology readiness, and users' perceptions of the AR-based marketing framework.

4.2 Demographic Profile of Respondents

Understanding the socio-demographic context of respondents is vital for interpreting their responses to questions regarding technology use and energy preferences. As shown in Table 4.1, the majority of respondents (49%) were aged between 18 and 24 years, suggesting a predominantly youthful population. This demographic is generally more receptive to digital innovations such as AR and mobile applications, making them a strategic target for technology-driven energy campaigns. Level of education of respondents was notably high. Thirty-six percent (36%) reported having completed university education, while another 29% had tertiary-level training. Together, 65% of respondents possessed higher education qualifications, which may contribute to a more informed and engaged user base, particularly in relation to understanding the environmental benefits of green charcoal and navigating mobile-based platforms.

Table 4.1: Demography of the respondents

Interview	Response	Frequency	Percentage
Age Bracket	18-24	49	49.00%
	25-34	17	17.00%
	35-44	24	24.00%
	45-54	6	6.00%
	55 and above	4	4.00%
What is your level of education?	Not attended any class	7	7.00%
	Primary level	5	5.00%
	Secondary level	23	23.00%
	Tertiary Institution	29	29.00%
	University	36	36.00%

This demographic context suggests a favorable setting for implementing mobile AR technologies. The youthful and educated population enhances the likelihood of successful user interaction with digital tools and supports the study‟s premise that AR can be a powerful awareness and marketing instrument in Northern Uganda.

4.3 Objective 1: To map out technology resources for green charcoal production and marketing.

The first objective of the study sought to map the existing technology resources supporting marketing of green charcoal. Data were collected using questionnaires administered to consumers, key informant interviews with producers and stakeholders, and an observation checklist conducted at production and marketing sites. The findings are presented by triangulating evidence from the three data sources. The triangulated findings indicate that the green charcoal sector possesses basic production resources but lacks adequate technological capacity for large-scale commercialization. While locally fabricated equipment enables production, producers continue to face challenges related to production efficiency, packaging, quality control, and marketing. Existing ICT resources, including smartphones and internet connectivity, provide opportunities for digital transformation but remain underutilized.

As shown in Table 4.2, a substantial proportion of respondents (77%) reported having used green charcoal as a cooking fuel. Among these users, 36% rated the experience as "very good" and 34% as "good," underscoring a generally positive user experience.

Table 4.2: Knowledge on green charcoal production and usage

Interview question	Response	Frequency	Percentage
Have you ever used green charcoal as a source of cooking fuel?	Yes	77	77.00%
	No	23	23.00%
How was the experience of using green charcoal?	Very good	36	36.00%
	Good	34	34.00%
	Fair	7	7.00%
	Bad	0	.00%
	N/A	23	23.00%
What is the challenge you have encountered while using green charcoal?	It is not easy to find them in the market	55	55.00%
	I do not know how to use it	2	2.00%
	It is difficult to light it	32	32.00%
	N/A	11	11.00%
Where do you always get your green charcoal from?	Supermarket	2	2.00%
	Nearby market	36	36.00%
	Others	58	58.00%
	N/A	4	4.00%
Is it accessible, available and reliable?	Yes	49	49.00%
	No	51	51.00%
What do you think can be done to solve this problem?	Increase in production	48	48.00%
	Green charcoal to be brought closer to the nearest market	43	43.00%
	Others	9	9.00%

However, barriers to continued or widespread use persist. A key challenge identified by 55% of respondents was limited market availability of green charcoal, while 32% cited difficulty in lighting the product. These findings point to structural barriers in supply and product usability, both of which constrain adoption despite a generally favorable perception of the product.

When asked about accessibility, responses were split: 51% found green charcoal to be inaccessible or unreliable. Participants recommended increasing production (48%) and bringing distribution points closer to end-users (43%) as practical solutions. This highlights the potential of AR as an awareness and education tool, capable of visualizing where to obtain the product and how to use it effectively.

The findings further reveal that consumer demand already exists, as evidenced by the high proportion of users reporting positive experiences. However, inadequate production capacity, weak marketing strategies, and poor access to market information significantly constrain wider adoption.

4.4 Objective 2: To design an Augmented reality-based framework for marketing green charcoal.

The second objective of the study sought to establish user requirements and technological capabilities necessary for designing an Augmented Reality (AR)-based framework for marketing green charcoal. Findings were obtained through questionnaires, key informant interviews, and an observation checklist. The results are presented by triangulating the three sources of data. The triangulated findings from questionnaires, key informant interviews, and observations informed the design of the Augmented Reality-based marketing framework.

As shown in Table 4.3, mobile phone ownership was nearly universal, with 97% of respondents reporting that they owned a mobile phone, of which 91% were smartphones. Digital transaction readiness was also high. Eighty-three percent (83%) of respondents had previously bought or sold products using mobile applications. Notably, 81% rated their digital experience as "easy" or "very easy," and 80% expressed interest in using mobile apps for ordering or marketing green charcoal. These figures demonstrate a strong digital foundation upon which AR framework can be deployed.

Table 4.3: Technology resources access

Interview	Response	Frequency	Percentage
Do you have a phone?	Yes	97	97.00%
	No	3	3.00%
What type of phone?	Smart phone	91	91.00%
	Basic phone	9	9.00%
Have you ever experienced buying or selling any product through an application on your phone?	Yes	83	83.00%
	No	17	17.00%
How was your experience?	Very easy	31	31.00%
	Easy	50	50.00%
	Not easy	8	8.00%
	Difficult	11	11.00%
Would you love to order or market your green charcoal online through your mobile device?	Yes	80	80.00%
	No	20	20.00%
What do you know about green charcoal as an alternative source of fuel for heating or cooking?	Can be used for cooking	19	19.00%
	Better alternative for heating and environment	41	41.00%
	Clean energy for cooking	30	30.00%
	No, I do not know about it	10	10.00%

The questionnaire findings established that the majority of potential users possess smartphones, have experience with mobile applications, and are willing to use digital platforms for purchasing and marketing green charcoal. Key informants identified the specific information and functionalities required by consumers, while observational findings confirmed the availability of essential ICT resources and demonstrated the usability of the prototype.

Based on these findings, the proposed AR framework was designed to include the following core components:

- Interactive augmented reality visualization of green charcoal products;
- Product descriptions and environmental benefits;
- Product pricing and availability information;
- Demonstration videos illustrating production and usage;
- Customer inquiry and communication features;
- Future integration of ordering and digital payment services.

4.5 Objective 3: To test the AR based framework in marketing green charcoal.

The third objective of the study aimed at testing the AR-based framework developed for marketing green charcoal. The objective assessed the framework's usability, relevance, and potential to address existing production and marketing challenges. Data were obtained from questionnaires, key informant interviews conducted after prototype demonstration, and observations made during prototype testing. The findings are presented by triangulating the three sources of evidence. The triangulated findings from questionnaires, key informant interviews, and observation checklists demonstrate that the developed Augmented Reality-based framework is both technically feasible and highly acceptable for marketing green charcoal.

Findings in Table 4.4 show that 77% of respondents were actively involved in a green charcoal production group. The most produced types of charcoal were round (37%) and long (29%), suggesting some diversity in product design based on user needs or production capacity. Primary clients of the producers included local communities (57%), hotels (15%), and students (8%), indicating a community-centered distribution network. While 71% affirmed that their production met consumer demand in terms of quality and quantity,

producers were heavily reliant on informal marketing channels. Word of mouth was the dominant strategy (74%), with minimal use of media advertising (0%) or newspaper coverage (5%).

Key constraints identified by producers included limited capital (44%), inadequate marketing skills (15%), and insufficient human resources (16%). Although these difficulties existed, confidence in digital transformation endured, there was optimism about digital transformation. About 59% believed online marketing would be "very helpful," and another 16% considered it "helpful." This supports the study‟s initiative to explore AR as a digital solution for bridging marketing gaps.

Table 4.4: Production and marketing of green charcoal

Interview	Response	Frequency	Percentage
Are you part of green charcoal production group?	Yes	77	77.00%
	No	23	23.00%
How many types of green charcoal does your group produce?	Round	37	37.00%
	Oval	3	3.00%
	Short	12	12.00%
	Long	29	29.00%
	Square	0	.00%
	N/A	19	19.00%
Who are your customers/clients for green charcoal produced?	Local community	57	57.00%
	Students	8	8.00%
	Hotels	15	15.00%
	Schools	1	1.00%
	Others	6	6.00%
	N/A	13	13.00%
Does your product quality and quantity meet the customer‟s demand?	Yes	71	71.00%
	No	16	16.00%
	N/A	13	13.00%
What is the current marketing strategy being used?	Word of mouth	74	74.00%
	Media advert	0	.00%
	Newspaper	5	5.00%
	Print media	0	.00%
	Others	8	8.00%
	N/A	13	13.00%
What are the challenges affecting the marketing strategy being used?	Inadequate capital resources	44	44.00%
	Limited Skills and knowledge	15	15.00%
	Limited human capital	16	16.00%
	Others	12	12.00%
	N/A	13	13.00%
How would you perceive online marketing application to improve on marketing of your products?	Very helpful	59	59.00%
	Helpful	16	16.00%
	Somehow	8	8.00%
	Not helpful	4	4.00%
	N/A	13	13.00%

The questionnaire findings show that producers are actively engaged in green charcoal production, currently rely on informal marketing strategies, and perceive the proposed application as a valuable marketing tool. Key informants confirmed that the prototype addresses critical challenges related to consumer awareness, product information, vendor identification, and communication between producers and consumers. Observation results further verified that users were able to interact successfully with the application and complete key tasks with minimal technical difficulties. Overall, the prototype demonstrated that the

proposed AR framework was technically functional, user-friendly, and capable of enhancing product visualization, consumer awareness, and communication between producers and consumers.

4.6 Objective 4: To evaluate the effectiveness of the Augmented Reality Framework

The fourth objective of the study sought to evaluate the effectiveness of the developed AR-based framework in enhancing the marketing of green charcoal in Gulu City and Amuru District. The evaluation focused on determining whether the framework could improve awareness, access to market information, communication between producers and consumers, and the overall promotion of green charcoal. Data were obtained through questionnaire responses, key informant interviews conducted after prototype testing, and observations recorded during prototype testing. The findings are presented through triangulation of these three data sources. The findings from the questionnaire indicate a high level of acceptance of the proposed digital solution. As presented in Table 4.6, 59% of respondents perceived the online AR marketing application as very helpful, 16% considered it helpful, 8% believed it would somehow improve marketing, while only 4% considered it not helpful. These findings imply that approximately three-quarters of the respondents believed that the proposed framework would substantially improve the marketing of green charcoal.

Key informants confirmed that the framework effectively addresses major challenges within the green charcoal value chain, including limited consumer awareness, inadequate market information, weak communication between producers and consumers, and poor product visibility. Observation results further demonstrated that the prototype is technically functional, user-friendly, and capable of supporting consumers in accessing product information and locating vendors. Although further improvements are required, particularly in internet optimization, GIS integration, and online transaction capabilities, the framework demonstrates considerable potential as an innovative marketing tool for promoting renewable energy products in Uganda.

4.7 Visualization of Unity AR based marketing framework Outputs

To complement the survey findings and evaluate the artefact's usability and engagement, visual outputs from the Unity AR framework were captured during simulation sessions. The framework was built with Unity 3D and AR Foundation, incorporating marker-based image recognition and 3D model rendering triggered by specific target images related to green charcoal.



Figure 4.1: *Shows the mobile AR application install on a mobile device.*

Illustrates the installed mobile Augmented Reality (AR) application as displayed on a mobile device. The figure provides a visual representation of the user interface of the developed application, which is designed to support the marketing of green charcoal in Amuru and Gulu City. It demonstrates how end-users interact with the application once it has been successfully installed on their devices. The application is optimized to run on Android devices with minimum hardware requirements, including Android API Level 34 (Android 14), at least 4GB of RAM, and a minimum of 128GB of internal storage. This ensures smooth performance and effective delivery of AR features within the targeted operational context. As seen in **(Figure4.1)**



Figure 4.2: *Shows what happen upon launching the app and AR camera targeting an Image.*

The figure illustrates the framework response after launching the mobile application and directing the AR camera toward a target image. Upon startup, the application activates the device camera and begins real-time image detection and recognition. Once the target image is

identified, the application overlays a message on the camera feed stating, “Looks like you are searching for ordinary charcoal”. **(Figure4.2)**

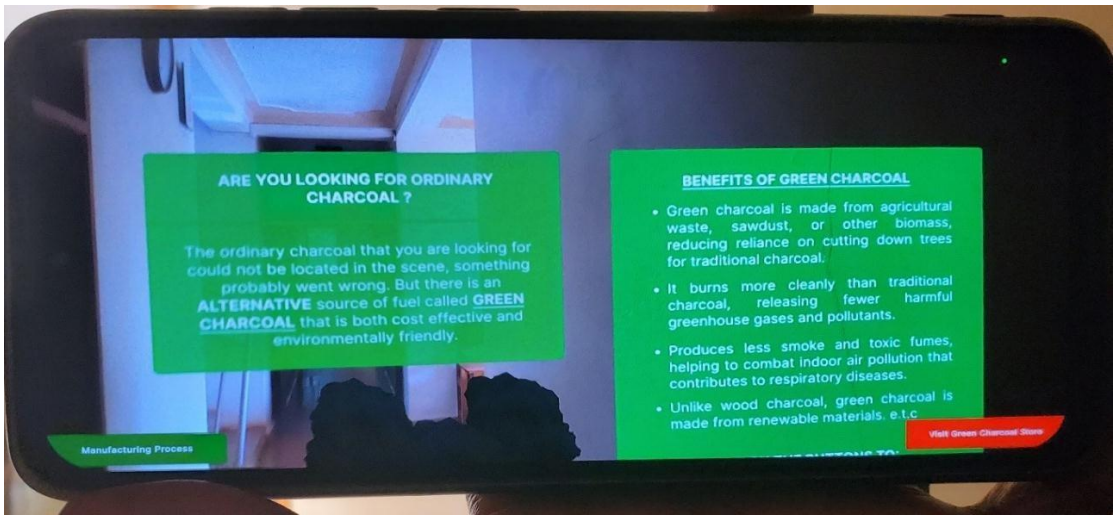


Figure 4.3: *Shows AR Visualization of Green charcoal image in a real-world environment*

demonstrates the application‟s response after the initial prompt, where the application presents alternative options by introducing green charcoal products through augmented reality (AR) visualizations. The AR-simulated images are overlaid onto the real-world environment, allowing users to view and interact with the products as if they were physically present. This figure highlights how the application extends the user experience beyond recognition by enabling interactive exploration of environmentally friendly charcoal options within the user‟s surroundings, thereby supporting users to make informed and sustainable decision-making. **(Figure4.3)**

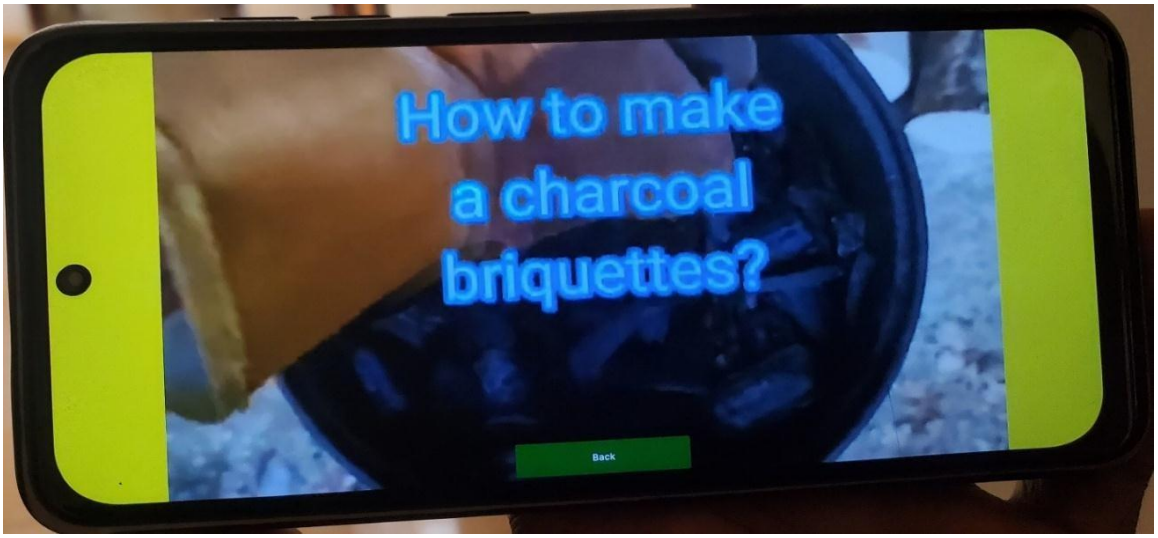


Figure 4.4: *Showing the interface on the production process of green charcoal.*



Figure 4.5: *Illustrating process of making green charcoal.*

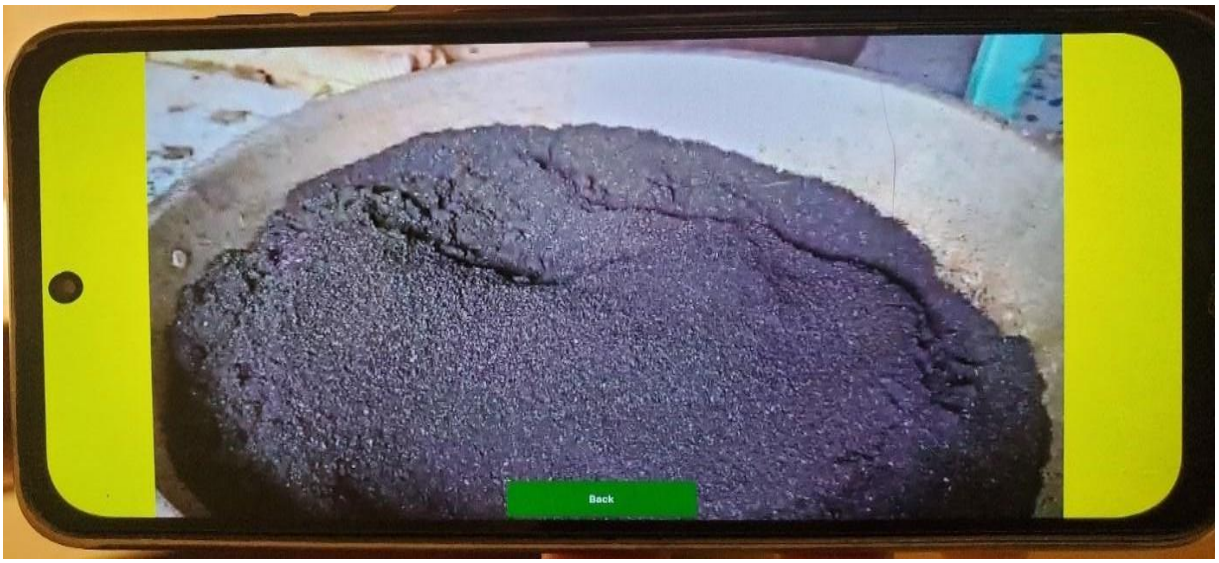


Figure 4.6: *Powder after crushing process to produce green charcoal.*

Figures 4.4, 4.5 and 4.6, illustrate the step-by-step user guidance provided by the application in the process of producing green charcoal. Through a structured and narrated sequence, the user is taken through the key stages of production, beginning with the collection of raw materials, followed by the carbonization process, and concluding with the packaging of the final product. The visual and audio guidance presented in these figures enhances user understanding by simplifying complex procedures into clear, sequential steps. This demonstrates how the application leverage practical, hands-on learning support, enabling users to effectively grasp and replicate the green charcoal production process.



Figure 4.7: *Illustrating the user testing session.*

These screenshots validate the artefact‟s technical feasibility and demonstrate how Unity's image tracking and content rendering pipeline function effectively in field conditions. Such visual storytelling strengthens user comprehension and enhances emotional engagement with the message of clean cooking solutions.

Chapter Five: Discussion

5.1 Introduction

This chapter offers a comprehensive interpretation of the results presented in Chapter Four, linking them to the study's objectives, relevant literature, and the broader context of sustainable energy transitions. The discussion emphasizes the potential role of augmented reality (AR) as a transformative tool in renewable energy marketing, particularly in low-resource settings such as Northern Uganda. The Unity-based AR marketing framework developed in this study assessed both the application technical functionality and its capacity to address information gaps, foster product awareness, and enable consumer engagement.

5.2 Objective 1: To map out technology resources for green charcoal production and marketing.

The interview findings revealed that green charcoal production in Gulu City and Amuru District largely relies on locally fabricated technologies. Carbonization is mainly conducted using locally constructed combustion machines, while the moulding of green charcoal briquettes is predominantly performed manually using simple locally fabricated equipment. These technologies are affordable but limit production efficiency and product quality.

Regarding marketing practices, the findings indicated that producers primarily depend on traditional methods such as word-of-mouth communication and customer referrals. Although some producers occasionally use mobile phones and social media platforms, the adoption of digital marketing remains minimal.

The key informant identified several technological challenges affecting the sector, including low production capacity and inconsistent product quality resulting from limited access to modern production equipment. Furthermore, producers have inadequate access to digital marketing platforms and media advertising channels, reducing product visibility and market reach. The informant suggested that introducing advanced production machinery alongside digital and media-based marketing technologies would significantly improve production efficiency, product quality, and market access for green charcoal producers.

The study results also confirm a strong level of digital readiness among the respondents. With 97% of respondents owning mobile phones, of which 91% are smartphones, the technological infrastructure necessary for AR adoption is well established. This is further supported by the fact that 83% of respondents had prior experience in using mobile apps for buying or selling

products. These insights align with reports by the Astuti & Ayinde, (2025), which underscore mobile phone access as a driver of digital inclusion in sub-Saharan Africa.

The willingness of 80% of respondents to use digital applications for marketing or ordering green charcoal reinforces the community‟s openness to innovation. This readiness offers a strategic entry point for introducing interactive digital tools such as AR. Notably, initial testing showed favourable responses to the Unity-developed AR prototype. Users found the simulation informative and engaging, indicating that immersive AR experiences can effectively substitute for physical demonstrations, especially in resource-limited environments. Pilot users described how the visual presentation of charcoal production, enhanced by biltilingual audio and text, helped them better understand the process and its environmental relevance. These findings echo the conclusions of Rauschnabel et al. (2024b), who observed that AR tools enhance user engagement, emotional connectivity, and product recall, particularly when personalized and context-aware elements are incorporated.

5.3 Objective 2: To design an Augmented reality-based framework for marketing green charcoal.

The key informant noted that consumers often experience difficulties locating vendors due to inadequate information regarding vendor locations and product availability.

To address these challenges, the proposed AR mobile application should display comprehensive product information including product prices, vendor locations, and the benefits of green charcoal. The informant further recommended that users should be able to submit inquiries through the application and receive timely responses from producers or vendors. Among the proposed application features, the most valuable were identified as, Product information, Vendor location services, Product pricing, Environmental benefits and Ordering services.

The major concern raised regarding adoption of the AR application was the cost associated with internet connectivity, which may limit accessibility for some users. However, the informant believed that users would be encouraged to adopt the application if it remained simple, easily accessible, and convenient to use.

Although 77% of participants had used green charcoal, the study uncovered several barriers that hinder its wider adoption. Among these, market inaccessibility (51%), limited availability (55%), and difficulty in lighting (32%) were cited as major issues.

These findings highlight persistent infrastructural and knowledge-based Persistent obstacles in achieving energy access literature. Similarly, Zainab Efe Egieya et al. (2023) point to distribution inefficiencies and lack of consumer education as critical obstacles to clean energy uptake in rural Africa.

The Unity-based AR application was specifically designed to address these barriers. By simulating the full lifecycle of green charcoal from raw material collection to final usage within a smartphone app, the framework offers an accessible and low-cost method for raising awareness Nawres et al. (2016) . Users without prior exposure to the product reported increased interest in trying it after interacting with the app. This suggests that AR can reduce uncertainty about unfamiliar products by enhancing understanding and perceived value Rai & Robinson, (2013). Additionally, by integrating practical guidance into the simulation (e.g., how to light green charcoal), the AR marketing framework contributes to behavioural change. Such functionality is particularly useful in addressing misconceptions and improving user confidence two factors identified in previous studies as essential for scaling clean energy adoption (Radu,(2014)) .

5.4 Objective 3: To test the AR based framework in marketing green charcoal.

After interacting with the developed AR prototype, the key informant expressed a positive first impression, indicating that the application has significant potential to promote awareness and encourage the use of green charcoal products.

The prototype was considered easy to understand and navigate. The demonstration feature illustrating the production process and proper usage of green charcoal was identified as the most useful component of the application because it enables consumers to visualize the product before making purchasing decisions. The ordering and purchasing functionality were identified as the feature requiring the greatest improvement. During prototype testing, poor internet connectivity affected application performance, highlighting the importance of designing the application to function efficiently under low-bandwidth conditions where possible. Overall, the usability of the prototype was rated at approximately **70%**, suggesting that while the application is functional and user-friendly, further refinements are necessary before full deployment.

The study found that 77% of respondents were part of a green charcoal production group. The primary forms produced included round (37%) and long (29%) briquettes, with customers mostly drawn from local communities (57%) and hospitality services. While most producers

(71%) claimed their product met customer expectations, marketing efforts remained largely informal. Word-of-mouth was the most cited method (74%), and very few used structured media channels.

Marketing challenges were compounded by limited capital (44%), skills (15%), and personnel (16%). These findings point to an urgent need for scalable and cost-effective marketing innovations. The AR prototype offers a promising alternative: it provides immersive educational content at low marginal cost, is compatible with widely owned mobile devices, and enables users to share product information visually and verbally. The data suggests that AR-based marketing framework can fill the gap left by weak traditional marketing frameworks. Their ability to deliver repeatable, high-quality content can help standardize product messaging and improve market penetration. By coupling educational simulations with mobile commerce integration, AR application can enhance consumer confidence, facilitate purchasing, and build brand trust.

5.5 Objective 4: To evaluate the effectiveness of the AR-based framework in promoting awareness and market access for green charcoal

To ensure reliability and usability, the application underwent rigorous testing and refinement. Performance optimization: The inference pipeline was optimized to maintain a stable frame rate of at least 30 frames per second (FPS), ensuring a smooth and responsive AR experience on mobile devices. The model was tested in complex real-world environments to minimize false positives, particularly avoiding misclassification of visually similar objects such as stones or dark surfaces.

The application emphasizes that green charcoal is produced from agricultural waste materials rather than wood, thereby contributing to reduced deforestation. The AR framework illustrates the relatively smokeless nature of green charcoal, which minimizes indoor air pollution and reduces respiratory health risks compared to traditional charcoal.

The key informant held that the AR framework has considerable potential to increase public awareness of green charcoal products. The framework was viewed as an effective platform for educating consumers on the environmental and economic benefits of green charcoal while simultaneously expanding market opportunities beyond the current production areas.

The informant also noted that the application potentially contributes to increased producer sales by improving product visibility and enabling consumers to obtain accurate product

information more easily. Furthermore, the application strengthen communication between producers and consumers by allowing customers to submit inquiries regarding product availability and order quantities.

The informant expressed willingness to recommend the application to other users because it serves as an educational tool that provides comprehensive information about green charcoal.

To enhance future versions of the application, the key informant recommended integrating Geographic Information System (GIS) functionality to enable consumers to easily identify and navigate to nearby green charcoal vendors. Such functionality would improve accessibility and strengthen market linkages between producers and consumers.

Chapter Six: Conclusion, and Recommendation

6.1 Summary of Key Findings

This study set out to access and evaluate a Unity-based AR marketing framework for promoting the marketing and adoption of green charcoal in Gulu and Amuru districts. The findings reveal a digitally prepared and demographically receptive user base. Green charcoal is generally well-received, but adoption is constrained by limited product availability, lighting challenges, and outdated marketing methods. The AR prototype addressed many of these issues by offering immersive simulations that enhanced awareness, product knowledge, and perceived ease of use. Production among community groups is active and seemingly adequate, but promotion remains limited to informal networks. The results demonstrate that AR can act as both an educational and marketing platform capable of scaling engagement across diverse user demographics. The pilot feedback supports the notion that AR, particularly when deployed on smartphones, has the potential to transform traditional energy awareness campaigns

The study has demonstrated that AR technology, when tailored to local needs and realities, can substantially enhance the visibility, understanding, and acceptance of renewable energy products. The Unity-based AR marketing framework developed in this study was able to bridge the information and engagement gaps commonly associated with low adoption of green charcoal in Uganda. The interactive, bilingual, and mobile-friendly features of the application ensured that it could be deployed in varied contexts, including rural and peri-urban areas. By using AR to simulate the production and benefits of green charcoal, the application moved beyond static awareness materials and provided a dynamic learning experience. The technique increased knowledge and contributed to positive behavioural intentions among users. The study reinforces the broader view that digital tools, particularly AR, can play a transformative role in sustainable development when implemented thoughtfully and inclusively

6.2 Conclusion

The first objective, which sought to map out the technological resources for green charcoal production and marketing, established that production in the study area largely depends on locally fabricated carbonization and moulding equipment, while marketing is predominantly conducted through traditional methods such as word-of-mouth referrals and limited use of digital platforms. The findings further revealed significant challenges, including low

production capacity, inconsistent product quality, limited access to advanced production technologies, and inadequate utilization of digital marketing tools. These findings underscored the need for an innovative technological solution capable of addressing both information and market access gaps.

Building on these findings, the second objective focused on designing an Augmented Reality-based framework that responds to the identified user needs and market challenges. The developed framework incorporated essential features such as product information, demonstrations of green charcoal production and usage, environmental benefits, pricing information, vendor locations, and communication channels between producers and consumers. The framework was designed to provide consumers with interactive, visual, and context-specific information, thereby supporting informed purchasing decisions while simultaneously promoting environmentally sustainable energy alternatives.

The third objective evaluated the usability of the developed prototype through user testing. The findings demonstrated that participants found the AR application easy to understand and navigate, with the interactive demonstrations being particularly valuable in explaining the production process and practical use of green charcoal. Although challenges such as internet connectivity and improvements to the ordering functionality were identified, the overall usability rating indicated that the prototype was functional, practical, and acceptable for its intended users. These findings demonstrate the feasibility of implementing AR technology as a digital marketing tool within the local context.

Finally, the fourth objective assessed the effectiveness of the AR framework in promoting awareness and improving market access. The evaluation showed that the application has strong potential to increase public awareness of green charcoal by providing engaging educational content that is more interactive than conventional promotional materials. The framework also enhances market access by connecting consumers with vendors, improving communication between producers and buyers, and expanding the visibility of green charcoal beyond traditional production areas. Consequently, the application has the potential to contribute to increased adoption of green charcoal, improved producer sales, and reduced dependence on environmentally destructive traditional charcoal.

Overall, the study demonstrates that AR technology, when designed to address local needs and supported by appropriate digital infrastructure, can significantly improve the marketing of renewable energy products. The Unity-based AR framework successfully bridged existing

information, communication, and engagement gaps by providing an interactive, bilingual, and mobile-friendly platform capable of operating in both urban and rural settings. By transforming conventional awareness campaigns into immersive learning experiences, the AR based marketing framework enhanced users' understanding of green charcoal, strengthened positive behavioural intentions, and increased confidence in the product. Beyond its contribution to green charcoal marketing, this research provides a practical framework for integrating emerging digital technologies into environmental conservation, renewable energy promotion, and sustainable development initiatives in Uganda and similar developing-country contexts. The findings further contribute to the growing body of knowledge on the application of Augmented Reality in sustainable marketing and demonstrate its potential as an innovative tool for advancing the achievement of Sustainable Development Goal 7 (Affordable and Clean Energy), Sustainable Development Goal 12 (Responsible Consumption and Production), and Sustainable Development Goal 13 (Climate Action).

6.3 Recommendation

Based on the study findings and application evaluation, the following recommendations are proposed.

- Local governments and NGOs should invest in scaling AR-based marketing for clean energy, targeting other regions beyond the geographical scope of the study with low adoption rates.
- Training workshops for green charcoal producers on digital marketing, content creation, and mobile AR deployment should be established to improve uptake and sustainability.
- Integration of local languages in AR applications will ensure inclusivity and increase understanding among diverse user groups.
- Public-private partnerships can support funding, content development, and technical training for long-term AR tool adoption.

6.4 Areas of Future Research

While this study focused on two districts, future research can extend the scope to include broader demographic and geographic contexts. Longitudinal studies are also recommended to assess the sustained impact of AR exposure on user behaviour and adoption rates. In addition, comparative studies between AR-based and conventional marketing strategies would offer a more thorough understanding of the cost-effectiveness and behavioural influence. Further

investigation into user interface design, device compatibility, and offline functionality will also enhance the robustness and scalability of AR based marketing framework. With AR's continued development, its convergence with emerging technologies like AI and IoT opens up new opportunities for enhancing clean energy solutions, communication and adoption across Africa. Future research should explore the integration of a multilingual component within the application to enable users to interact in their preferred languages, thereby enhancing accessibility and user experience. This was not fully realized in the current study due to time constraints.

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Appendices

Appendix I: Screen shots from field testing







Appendix II: Questionnaires

Introduction

My name is ACIRO GLADYS, I am a student of Gulu University offering Masters of science in Information and Communication Technology 21/U/2700/MID/PS I am seeking your support to participate in this research to help me in completing my study. Participation in this study is on voluntary basis any information given here shall be confidential, your positive responds is highly appreciated. thanks

Name

Age Bracket

(A) 18-24
(B) 25-34
(C) 35-45
(D) 45-54
(E) 55+

What is your level of education?

(A) Not attended any class
(B) Primary level
(C) Secondary level
(D) Tertiary Institution
(E) University Degree

SECTION 1

1. Have you ever used green charcoal as a source of cooking fuel?
   (A) Yes
   (B) NO
2. If No why?

3. If Yes

4. How was the experience of using it?
   (A) Very good
   (B) Good
   (C) Fair
   (D) Bad
5. What is the challenge you have encountered while using green charcoal?
   (A) It is not easy to find them in the market
   (B) I do not know how to use it
   (C) It is difficult to light it

6. Where do you always get your green charcoal from?
   (A) Supermarket
   (B) Nearby Market
   (C) Others
7. Is it accessible, available and reliable?
   (A) Yes
   (B) No
   If No then go to 8
8. What do you think can be done to solve this problem?
   (A) Increase in production
   (B) Green charcoal to be brought closer to the nearest market
   (C) Others

SECTION 2

9. Do you have a phone?
   (A) Yes
   (B) No

10. What type of phone
    (A) Smart Phone
    (B) Small Phone
11. Have you ever experience buying or selling any product through an application on your phone

(A) Yes

(B) No

12. How was your experience?

(A) Very easy

(B) Easy

(C) Not Easy

(D) Difficult

13. Would you love to order or market your green charcoal online through your mobile device?

(A) Yes

(B) No

14. What do you know about green charcoal as an alternative source of fuel for heating or cooking?

(A) Can be used for cooking

(B) Better Alternative for heating and environment friendly

(C) Clean energy for cooking

(D) No, I do not know about it

SECTION 3

15. Are you part of any green charcoal production group?

(A) Yes

(B) No

16. How many types of green charcoal does your group produce?

(A) Round

(B) Oval

(C) Short

(D) Long

(E) Square

17. Who are your customers/Clients for the green charcoal produced?

(A) Local community

(B) Students

(C) Hotels

(D) Schools

(E) Others

18. Does your product quality and quantity meet the customers‟ demands?
    (A) Yes
    (B) No
19. If No? then why so?

20. What is the current marketing strategy being used to promote your product now?

    (A) Word of mouth
    (B) Media advert
    (C) Newspaper
    (D) Print media
    (E) Others
21. What are challenges affecting the marketing strategy being used?
    (A) Inadequate capital resource
    (B) Limited skills and knowledge
    (C) Limited human capital
    (D) Others
22. How would you perceive online marketing system to improve on marketing of your products?
    (A) Very helpful
    (B) Helpful
    (C) Some how
    (D) Not helpful

Appendix III: Key Informant Interview Guide

Section A: Background Information

i. What is your role in relation to green charcoal production, distribution, environmental management, or marketing?
ii. How long have you been involved in this sector?
iii. What are your major responsibilities?

Section B(i): To map out technology resources for green charcoal production and marketing

Technology Resources

1. What technologies are currently used in green charcoal production?
2. What equipment or tools are commonly used during production?
3. What technologies are used to market green charcoal products?
4. Do producers use mobile phones, social media, radio, television, or other platforms to market their products?
5. What challenges do stakeholders face when using the technology for production and marketing?
6. What technological resources are lacking in Gulu and Amuru districts?
7. How can technology improve green charcoal production and marketing?

Section B(ii): To design an Augmented Reality-based framework for marketing green charcoal

User Requirements

8. What information would consumers need before purchasing green charcoal?
9. What difficulties do consumers face when searching for green charcoal vendors?
10. What information should be displayed in a mobile application for green charcoal marketing?
11. How would you like customers to interact with the proposed AR framework?
12. What features would make the AR framework useful?

a) Product information
b) Vendor location
c) Prices
d) Product demonstrations

e) Environmental benefits

f) Ordering services

13. What concerns might users have when using an AR application?

14. What factors would encourage people to use the proposed system?

Section B(iii): To test the AR-based framework

Prototype Testing

15. After viewing the prototype, what is your first impression of the system?

16. Was the system easy to understand and use?

17. Which features did you find most useful?

18. Which features require improvement?

19. Were there any technical difficulties encountered during testing?

20. How would you rate the usability of the system?

Section B(iv) 4: To evaluate effectiveness of the AR system

Effectiveness Evaluation

21. Do you think the AR application can increase awareness about green charcoal?

22. How can the application improve access to green charcoal markets?

23. Do you think the application can increase sales for producers?

24. How can the application improve communication between producers and consumers?

25. Would you recommend the application to other users? Why?

26. What additional features should be included in future versions?

27. Any other comments or recommendations?

Appendix IV: Observation checklist for green charcoal production and marketing

Research Title:
Augmented Reality-Based Framework for Marketing Green Charcoal in Gulu and Amuru Districts

Date: _____
Location: _____
Observer: _____

A. Production Resources

□ Production site available
□ Production equipment available
□ Carbonization equipment available
□ Briquette moulding equipment available
□ Drying facilities available
□ Storage facilities available
□ Packaging materials available
□ Safety equipment available no

B. Product Characteristics

□ Green charcoal available
□ Product properly packaged
□ Product labelled
□ Product size standardized
□ Product quality appears consistent
□ Product ready for market

C. Marketing Practices

□ Product displayed for customers
□ Posters or banners available
□ Product promotion activities observed
□ Social media marketing being used
□ Mobile phone marketing being used
□ Vendor records maintained

Appendix V: Introduction Letter from the Faculty of Science

GULU UNIVERSITY

P.O. Box 166
Gulu, Uganda

Tel: +256 471432106
FAX+256 471432094
Email: fs@gu.ac.ug

OFFICE OF THE DEAN FACULTY OF SCIENCE

11th October 2023,
To whom it may concern,

Dear Sir/Madam,

RE: Letter of Introduction

I am writing to introduce **Ms. Aciro Gladys, Reg. 21/U/2700/MID/PS** who is a postgraduate student pursuing Master of Science degree in Information Communication Technology for Development at the Faculty of Science, Gulu University. Ms. Aciro Gladys will study "**an augmented Reality (AR) Framework for Marketing of Green Charcoal in Amuru and Gulu districts, northern Uganda**" as part of her MSc work. The study shall be conducted for one year in the study districts.

Please accord her the necessary help during her research process.

Thank you,
Yours faithfully,

Malinga Geoffrey Maxwell (PhD)
Dean Faculty of Science,
Faculty of Science,
Gulu University,
P.O. Box 166, Gulu, Uganda,
Mobile: +256772893791
Email: geoffrey.malinga@gu.ac.ug

Appendix VI: Approval from GREC

GULU UNIVERSITY

P.O. Box 166, Gulu (U)
Website: www.gu.ac.ug
Email: gurec@gu.ac.ug

Tel: +256 471 432 096
Fax: +256 471 432 913
Mob: +256 772 305 621
+256 776 812 147

RESEARCH ETHICS COMMITTEE

14/03/2024

To: Gladys Aciro

Gulu University
0774618555

Type: Exempt

Re: An Augmented Reality Framework for Marketing of Green Charcoal in Amuru and Gulu District Northern Uganda

This is to inform you that the **Gulu University REC** held on **14/03/2024** reviewed the initial submission of the above-named study and granted conditional approval. The committee however noted the following that need to be addressed;

Background

You may leave out the pie chart since the same statistics are within the text.

Define green charcoal at the background. What is it not what is made from?

Describe the possible negative impact of green charcoal on the environment – for instance when the plant residues are not deposited in gardens as source of manure.

Mention the respiratory diseases associate with the traditional cooking fuel.

How did you get the information from women in Paboo, when, how and purpose? This has some ethical concerns.

Was the data from a preliminary study?

Make sure your paragraphs connect well with each other. One paragraph should describe one concept and its subcomponents. The paragraph where AR is described does not connect with the preceding one.

Clearly define Augmented Reality.

What is marketing in the study context? Write in full form 2D and 3D.

Problem statement

Let you problem sound like a problem. Try and describe the cause and the effects of the problem.

Objectives

Ask question about the reasons for lack of awareness.

Review and identify and evaluate the technologies that can address the problem.

Propose the AR framework relevant to the problem.

You may then empirically test the AR framework and give recommendations base on the results. All the above are suggestions for you to consider.

Significance

Describe separately the research contributions, practical contributions and theoretical contributions. The ethical issues you should take care of are the contributions to participants or community for that matter.

Literature review

The way how green charcoal is identified is not clear. How do you determine the types of green charcoal?

Methodology

You have started describing research paradigms. Justify the selection of the paradigms and do they link with the problem, questions, theory and data. In other words, the ontology – nature of reality, epistemology-what type of knowledge, methods – quantitative, qualitative or both etc.

What type of pilot testing will you carry-out with academician and they are not part of users of green charcoal. How will you access academicians, where, how many are they and reasons for selecting this group?. What will you use the results of pre-test for? Again this has some ethical concerns including access and demonstrating the purpose for pretesting and use of data.

What is the basis for selecting 100 households? You need to clarify this part.

Describe sampling plan adequately – describe the inclusions and exclusions criteria and their justifications.

Show where you will use descriptive, experimental and factor analysis – which objectives and what are the justifications of using them? There is also the aspect of multiple regression, meaning that all the analysis plan needs careful review.

Where did you get the 500 people which was the basis for you sample size? – if the study is not representative it is not good because you may make wrong conclusions,

Describe your data organization and management plan

Describe your analysis plan based on research questions or objectives. This should have details.

It will be ethically wrong if all the diagrams have no sources.

In the questions/tool – what is small phone?

Ethical considerations

Mention the office, officers or individuals where you will get permissions.

How will you handle issues of confidentiality, data protection and compensation of participants?

How will consenting be done? Describe how you will do it.

State the Study limitations This should be methodological in nature State the dissemination strategy Informed consent form (ICF):

- We observe that under the section of „Participants in the study"; the researcher mentions that „The respondentswill be 60 for the quantitative data while for qualitative data it will be any number beginning from 8 up to 60"; However, the selected study methodology did not mention anything about qualitative data collection, neither is there a qualitative data collection tool. Is the study a mixed method?
- The ICF should state the appropriate time it will take to interview or collect data from the respondent.
- Under the section of benefits: What benefits will participants get from the study, immediate or in the future? Thebenefits should be tailored according to the participants.
- Time compensation: Interviews can be lengthy, implying consuming the productive time of the participant and itcan also be stressful. It"s only fair that participants time is compensated or refreshment given to the participants. • Under the section of voluntarism of the ICF, state the contact of the, Chairperson, Gulu University Research

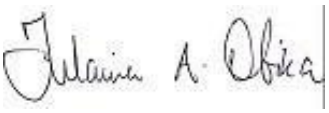
Ethics Committee, as Dr. Julaina A. Obika Tel: No., 0772964491; email: j.obika@gu.ac.ug ; and the Uganda

National Council for Science and Technology, on plot 6 Kimera road, Ntinda, Kampala on Tel 0414705500

In the attachment list there is a file named 'COVID-19 & EBOLA risk management plan for the study'. Since the country was declared ebola free, rename this file as 'COVID-19 risk management plan for the study'. When attaching this file into the system, scroll down the list of items on the attachment menu, select the option of 'Other' under the list of items in the attachment menu, and then manually rename the file as 'covid-19 risk management plan'.

No.	Document Title	Language	Version Number	Version Date
1	Informed Consent forms	ENGLISH	1	2024-02-21
2	COVID-19 & EBOLA risk management plan for the study		1	2024--21
3	Data collection tools	ENGLISH	1	2024-02-21
4	Protocol	English	1	2024-02-21

Yours Sincerely



Julaina A. Obika (PhD)

For Gulu University REC

Appendix VII: Source code

```
using System.Collections;
using System.Collections.Generic;
using System.Reflection.Emit;
using System.Threading;
using System.Threading.Tasks;
using Unity.InferenceEngine;
using Unity.XR.CoreUtils;
using UnityEngine;
using UnityEngine.Rendering;
using UnityEngine.SceneManagement;
using UnityEngine.UI;
using UnityEngine.UIElements;
using UnityEngine.XR.ARFoundation;
using UnityEngine.XR.ARSubsystems;
using static UnityEngine.EventSystems.EventTrigger;
using Button = UnityEngine.UI.Button;
// Removed the incorrect Unity.Sentis namespace reference
public class Detection : MonoBehaviour
{
    public ModelAsset modelAsset;
    public Texture2D inputImage;
    public Text txt;
    public Text status;
    public Button store;
    public Button video;
    public GameObject prefabToPlace;
    public string url = "https://divinebamboo.com/products/#charcoal-briquettes";
    public ARCameraManager cameraManager;
    public bool useCameraTexture = true;
    private Model runtimeModel;
    private Worker worker;
    private float txtConfidence = 0.0f;
    private GameObject spawnedObject;
    private bool detectionEnabled = true;
    private int frameCount = 0;
    private Texture2D cameraTexture;
    private const int INPUT_SIZE = 640;
```

```
private const float CONFIDENCE_THRESHOLD = 0.5f;
private const float IOU_THRESHOLD = 0.4f;
private SynchronizationContext unityContext;
void Start()
{
   store.gameObject.SetActive(false);
   video.gameObject.SetActive(false);
   txt.gameObject.SetActive(true);
   status.gameObject.SetActive(true);
   Screen.orientation = ScreenOrientation.LandscapeLeft;
   Screen.autorotateToPortrait = false;
   Screen.autorotateToPortraitUpsideDown = false;
   Screen.autorotateToLandscapeLeft = true;
   Screen.autorotateToLandscapeRight = true;
   unityContext = SynchronizationContext.Current;
   cameraManager = GetComponent<ARCameraManager>();
   try
   {
      runtimeModel = ModelLoader.Load(modelAsset);
      worker = new Worker(runtimeModel, BackendType.GPUCompute);
      InvokeRepeating(nameof(Update), 0f, 0.033f);
      if (cameraManager == null)
      {              cameraManager = FindAnyObjectByType<ARCameraManager>();
      }
   }
   catch (System.Exception e)
   {
      Debug.LogError($"Failed to load model: {e.Message}");
   }       store.onClick.AddListener(goToStore);
   video.onClick.AddListener(goToVideo);
}
public void goToStore() => Application.OpenURL(url);
public void goToVideo()
{       LoaderUtility.Deinitialize();
   SceneManager.LoadScene(1);
}
void OnEnable() {
   cameraManager.frameReceived += OnCameraFrameReceived;
}
void OnDisable() { cameraManager.frameReceived -= OnCameraFrameReceived; }
private Texture2D ConvertXRCpuImageToTexture2D(XRCpuImage image)
{       var conversionParams = new XRCpuImage.ConversionParams
   {           inputRect = new RectInt(0, 0, image.width, image.height),
      outputDimensions = new Vector2Int(image.width, image.height),
```

```
        outputFormat = TextureFormat.RGBA32,
        transformation = XRCpuImage.Transformation.MirrorY
      };
      if (cameraTexture == null || cameraTexture.width !=
conversionParams.outputDimensions.x || cameraTexture.height !=
conversionParams.outputDimensions.y)
      {           cameraTexture = new Texture2D(
          conversionParams.outputDimensions.x,
          conversionParams.outputDimensions.y,
          conversionParams.outputFormat,
          false           );
      }       var rawTextureData = cameraTexture.GetRawTextureData<byte>();
      image.Convert(conversionParams, rawTextureData);
      cameraTexture.Apply();
      return cameraTexture;
   }    void Update()
   {    }
   IEnumerator RunModel(Tensor inputTensor)
   {       worker.Schedule(inputTensor);
      yield return new WaitUntil(() => worker.PeekOutput() != null);
      using (Tensor<float> outputTensor = worker.PeekOutput() as Tensor<float>)
      {           float[] results = outputTensor.DownloadToArray();
        var iteration = outputTensor.shape[2];
        float center_x = 0.0f;
        float center_y = 0.0f;
        float box_w = 0.0f;
        float box_h = 0.0f;
        float confidence = 0.0f;
        for (int i = 0; i < iteration; i++)
        {               txtConfidence = results[(iteration * 4) + i];
          if ((results[(iteration * 4) + i] > 0.69f) && (results[(iteration * 4) + i] <= 1.0f))
          {                   if (results[(iteration * 4) + i] > confidence)
            {                       center_x = results[(iteration * 0) + i];
              center_y = results[(iteration * 1) + i];
              box_w = results[(iteration * 2) + i];
              box_h = results[(iteration * 3) + i];
              confidence = results[(iteration * 4) + i];
              status.text = "Status: Object Detected ";
            }               }
        }           if (confidence > txtConfidence)
          txtConfidence = confidence;
        txt.text = $" Confidence: {txtConfidence} : {frameCount}";
        if (confidence > 0.0f)
        {               float screenX = center_x / Screen.width;
```

```
            float screenY = center_y / Screen.height;
            Vector3 offset = (Camera.main.transform.forward * 2f) +
                        (Camera.main.transform.right * (screenX - 0.5f)) +
                        (Camera.main.transform.up * (screenY - 0.5f));
            Vector3 worldPos = Camera.main.transform.position + offset;
            GameObject anchorObject = Instantiate(prefabToPlace, worldPos,
Quaternion.identity);
            anchorObject.AddComponent<ARAnchor>();
            store.gameObject.SetActive(true);
            video.gameObject.SetActive(true);
            txt.gameObject.SetActive(false);
            status.gameObject.SetActive(false);
            detectionEnabled = false;
        }           outputTensor?.Dispose();
        inputTensor?.Dispose();
    }   }
  public void prefabPlacementIfNoDetection()
  {       Instantiate(prefabToPlace, new Vector3(0, 0.5f, 1), Quaternion.Euler(-90, 0, 0));
  }    void OnCameraFrameReceived(ARCameraFrameEventArgs args)
  {       frameCount++;
     if (detectionEnabled)
     {          if(frameCount == 2000)
        {
            detectionEnabled = false;
            store.gameObject.SetActive(true);
            video.gameObject.SetActive(true);
            txt.gameObject.SetActive(false);
            status.gameObject.SetActive(false);
            prefabPlacementIfNoDetection();
            return;
        }          if (frameCount % 20 == 0)
        {             if (cameraManager != null && cameraManager.isActiveAndEnabled)
           {                 try
              {                    if (cameraManager.TryAcquireLatestCpuImage(out
XRCpuImage image))
                 {                       cameraTexture =
ConvertXRCpuImageToTexture2D(image);
                    Tensor<float> inputTensor = TextureConverter.ToTensor(cameraTexture,
INPUT_SIZE, INPUT_SIZE, 3);
                    StartCoroutine(RunModel(inputTensor));
                    image.Dispose();
                 }                    else
                 {                       txt.text = $" Confidence: No Camera Feeds";
                 }               }
```

```
            catch (System.Exception e)
            {                   txt.text = $" Confidence: {e.Message}";
            }           }
          else
          {                 txt.text = $" Confidence: Camera Manager Not Active";
          }         }       }   }
   void OnDestroy()
   {       worker?.Dispose();
      cameraManager.frameReceived -= OnCameraFrameReceived;
   }}
sing UnityEngine;
using UnityEngine.SceneManagement;
using static UnityEngine.EventSystems.EventTrigger;
using Button = UnityEngine.UI.Button;
using UnityEngine.XR.ARFoundation;
#if UNITY_EDITOR
using UnityEditor;
#endif
public class Back : MonoBehaviour
{   public Button back;
   void Start()
   {       Screen.orientation = ScreenOrientation.LandscapeLeft;
      back.onClick.AddListener(goBack);
   }   public void goBack()
   {       LoaderUtility.Initialize();
      SceneManager.LoadScene(0);
   }   void Update()
   {       }}
```