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Preliminary Research Results on Exploring the Business Ecosystem and the Value Sources of Metaverse

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Abstract: Metaverse has become an emerging trend for both academia and industry, and it seems to concern the next generation of the Internet. Although it is still in its grassroots, metaverse is estimated to bring disruption to people's lives. One of the effects concerns the generation of new value opportunities that don't exist in real life. These new types of value as well as their impact on people's lives must be explored. In this respect, this paper utilizes literature evidence to define the value types of metaverse, which are circulated with experts from the focus group on metaverse of the International Telecommunications Union. Results uncover economic, public, and social values that metaverse generates, which can ensure its financial viability and the community's social sustainability. The economic value sources come from both the industrial and the commercial sectors, while the public values concern citizen empowerment and government efficiency. The social values of metaverse concern employment growth, and the provision of immersive experiences in entertainment and education environments. Finally, this paper critically reviews their role for environmental, economic, and social sustainability. The literature review indicated that metaverse can on the one hand, enhance sustainability but on the other hand, it can cause environmental impact.

Keywords: metaverse; business ecosystem; value; public value; sustainability

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1. Introduction

Although metaverse has been discussed during the last decades, only recently the advancement of digital technologies such as the Internet of Things (IoT), digital twins, augmented reality (AR), virtual reality (VR), artificial intelligence (AI), blockchain, etc. can make it a reality [1]. Metaverse has recently been defined by standardization bodies as the International Telecommunications Union (ITU) Focus Group on Metaverse which defined metaverse as "an integrative ecosystem of virtual worlds offering immersive experiences to users, that modify pre-existing and create new value from economic, environmental, social and cultural perspectives" [2]. As this definition incorporates not only the economic aspect, but also social and cultural perspectives, it is evident that metaverse will not only function as a business ecosystem that offers opportunities for economic growth but also as a medium that provides users with certain spiritual and emergent experiences, generating social and public values.

It is estimated that metaverse will present numerous prospects for value generation, which can strengthen several industrial sectors. Bloomberg analysts have suggested that the global metaverse revenue opportunity could reach $800 billion in 2024, compared to the $500 billion that was gained in 2020 [3]. Moreover, according to McKinsey, 59% of consumers are excited about transitioning their everyday activities on metaverse [4], while Gartner [5] highlighted that 25% of users will spend at least one hour per day on metaverse in 2026, prognosticating a transformative impact on people's daily lives. Based on the above inputs research was conducted in three scientific repositories (Web of Science, Scopus, and ScienceDirect) using the keywords metaverse AND value AND sustainability.

The research has returned several results that were studied. To the best of our knowledge, there is currently any article addressing the value sources of metaverse and their role for environmental, economic, and social sustainability. However, according to their currency, coverage, authority, accuracy, and objectivity their findings were concluded in this article.

According to the information provided, this article aims to examine the metaverse value sources and their roles in environmental, economic, and social sustainability.

More specifically, this article grounds the following research questions:

RQ1. *What kind of values can metaverse generate?*

RQ2. *What is the estimated impact on people's lives?*

RQ3. *What is the role of these values in sustainability?*

All these questions are important to be answered since metaverse evolved from the realm of science fiction to reality and can fundamentally affect the global economy, considering the potential market opportunities and consumers' interests, while its influence extends across almost every aspect of people's lives encompassing employment, entertainment, socializing as well as the natural environment in terms of its energy efficiency, community itineraries' reduction, etc. In addition, the above research questions give rise to 3 hypotheses that we would like to confirm:

H1. *Metaverse can generate economic, public, and social value.*

H2. *Metaverse can bring about changes in people's daily lives.*

H3. *The generated values can affect environmental, economic, and social sustainability.*

The remainder of this article is structured as follows: Section 2 contains the theoretical background of this article, defining corresponding terminology and highlighting the state of the art in literature. Section 3 contains the research methodology of this article, which is the focus group on metaverse launched by the International Telecommunications Union (ITU) [6] and the results. Finally, Section 4 contains some conclusions, the limitations, and future thoughts.

2. Background

This section explains the theoretical background that relates to this article's subject, including value and metaverse, while it explores the metaverse business ecosystem.

2.1. The Concept of Value

The concept of value has been explored for long by scholars who work in various scientific disciplines. The value represents the "worth, utility or significance of an entity", conforming to normative standards and therefore perceived as a desirable objective devoid of further justification or reasoned argumentation [7]. Moreover, the value theory refers to the process of value exchange, concerning goods and services. Value is an important pillar of the economy, and many economists have worked around its definition. According to Haksever et al. [8] "value is the equilibrium price formed when the marginal cost equaled the marginal utility". Furthermore, according to Porter "value is the amount that buyers are willing to pay for what a firm provides them. Value is measured by total revenue . . . A firm is profitable if the value it commands exceeds the costs involved in creating the product" [9]. Bowman and Ambrosini [10] claim that the value takes two forms, the first one is the exchange value, which is "the price paid for the use value created" and is realized when the sale occurs; and the second one refers to the perceived use value, which is a subjective assessment made by the customer who uses consumer surplus (gain) as the criterion in making purchase decisions.

Furthermore, Windsor [11] claims that "value creation is the generation of a surplus from trade, other transaction, investment, or relationship." It is present in any instance

wherein a voluntary transaction occurs. One of the most representative examples of creating shared value -the combination of economic and social value generation- is the producer-consumer relationship [12]. In the case of financial transactions, value creation can be considered as one of the primary objectives.

According to Jones et al. [13], economic value is "the combination of consumer surplus (retained by the consumer) on the demand (buyer) side and the cost of production and profit (producer surplus) on the supply (seller) side" [11]. Economic value can be created in three main ways, through voluntary trade or exchange, through producer innovation, and through a beneficial externality from trade or innovation [11].

Taking into account the customer perspective, according to the utility theory [10], consumers spend their income to maximize the level of satisfaction they derive from products or services. Total utility is the satisfaction people derive from owning a good, while marginal utility is the satisfaction people derive from owning one extra unit of a good or the satisfaction, they lose by giving up one unit, underlining the necessity for consumers to fulfill their requirements. Boulding [14] emphasized that fulfilling people's spiritual and intangible demands in addition to their financial ones is a crucial part of the concept of value. Extending beyond the confines of traditional economic analysis, Boulding explores the intricate relationships between society, religion, and ethics and their influence on human behavior and societal dynamics.

Public value, on the other hand, is designed for the public good and represents the value that an organization or an activity contributes to the society [15]. Public value is intended to furnish managers with an understanding of how business activities can contribute to the common good. Contemporarily, public value generation is not limited to the public sector, and it can be offered by non-governmental organizations (NGOs) or private enterprises.

Public value has four key dimensions [16]:

- Outcome achievement (the extent to which a public body enhances the impact of its mission).
- Trust and legitimacy (the extent to which an organization and its activities are trusted and perceived to be legitimate by the public and the key stakeholders).
- Service quality (the extent to which services are experienced as being delivered in a high-quality manner that is considerate of users' needs).
- Efficiency (the extent to which an organization maximizes the delivered benefits with minimal resources).

Public values provide a normative consensus about the rights, benefits, and prerogatives to which citizens should (and should not) be entitled. Moreover, they define the obligations of citizens to society, the state, and one another, and the principles on which governments and policies should be based [17]. In addition, public value is the combined view of the community about what they consider important [18].

Finally, social values can be defined "as standards, which individuals and social groups employ to define personal goals and essentially shape the nature and form of social order in a collective manner i.e., what is acceptable and not acceptable, what ought or not to be, what is desirable or non-desirable" [19–21]. Social value involves the relative importance that people attribute to their well-being changes and helps them leverage their acquired insights to enhance decision-making processes. In this respect, social value constitutes the expansive framework in which economic value or stakeholder value finds its definition [22].

2.2. Metaverse

Metaverse is a compound word composed of the words "meta" (meaning beyond) and "verse" (short for universe), signifying a universe beyond the real world. The first appearance of the term can be placed in 1992, in the science fiction novel "Snow Crash" [23], written by Neal Stephenson, in which metaverse is depicted as an alternate virtual world that users have access to through employing an avatar—a digital representation of a

person's physical identity—as a medium. Following its inception, the idea of metaverse has been discussed for several decades. However, metaverse has now transitioned from a realm of science fiction to practical application. Today, it appears that metaverse is much more than just a virtual environment and it holds the capability to affect practically every sector of people's lives. Ball [1] highlights its potential transformative impact on society as a whole while Almeida [24] focuses on the implications of metaverse for regional development and sustainability. Suganya & Kalaivani [25] outline the opportunities and challenges that metaverse offers to people, businesses, governments, and society as a whole, affirming its significant influence on people's livelihoods. Metaverse can be implemented in several sections concerning people's lifestyles including work, games or social interactions, retail or fashion, education, and events. Regarding the industrial sector, according to a survey conducted by Nokia [26], 50% of enterprises believe that the industrial metaverse will be a "real game changer", offering the greatest potential to sectors such as manufacturing, banking, healthcare, and transportation.

The development of metaverse is contingent upon the underlying connectivity and computational infrastructure. The five building elements of metaverse encompass the following concepts and technologies:

- Infrastructure (networks and connectivity, computing power, storage capacity, sensing or perception, cloud or edge infrastructure).
- Human augmentation (mobile devices such as headsets, smart glasses, and other wearables, creation platform and, assets).
- Digital identity (avatar, agent, social graphs, security, privacy).
- Economic enablers (blockchain, cryptocurrency, Non-Fungible Token, commerce, transactions).
- Ecosystem (entertainment, education, sports, industrial applications, regulations) [27].

Nevertheless, the evolution of metaverse will not simply be led by major technology players. Ample opportunities exist for everyone driving innovation to create real value in this space. Metaverse is a complex system that involves a wide range of stakeholders. Companies and organizations from all spheres come together to build an ecosystem where people and businesses can interact, work, socialize, entertain, and transact.

2.3. The Business Ecosystem of Metaverse

Ecosystems are generally defined as aggregations of organisms engaging in mutual interactions, denoted as complex networks of interdependent resources [28] while Anthopoulos [29] enhances the aforementioned definition and conceptualizes them as social systems wherein diverse stakeholders, institutions, tangible infrastructures, and resources demonstrating interdependence. According to Tafti et al. [30] the term "business ecosystem" can be attributed to Moore in 1993, and was subsequently developed by a multitude of scholars who scrutinized it through diverse perspectives. Moore defines a business ecosystem as an economic community sustained by a framework of interrelated organizations, individuals, and various elements of the business domain [31]. In accordance with this definition, this ecosystem encompasses customers, lead producers, competitors, and assorted stakeholders [32].

Metaverse has already drawn interest from a variety of organizations and vendors, which belong in different landscapes and structure a complex ecosystem where interaction, collaboration, and socialization between both individuals and businesses take place. Figure 1 illustrates a representative view of the metaverse ecosystem, which is characterized by its rapid and dynamic emergence.

Figure 1. Metaverse Ecosystem [33].

The above figure highlights the following existing categories with their representative stakeholders [33]:

- Centralized Metaverse Gateways (i.e., horizon NEOS©, FORTNITE©, ROBLOX©, SECOND LIFE© etc.) and Decentralized Metaverse Gateways (i.e., SANDBOX©, Decentraland©, SOMNIUM SPACE© etc.).
- NFT (non-fungible tokens) PFP Collections (i.e., Veefriends©, world of women©, DEADFELLAZ© etc.).
- Social & Meeting Hubs (i.e., ZOOM©, SpatialChat©, FACEBOOK©, Gather© etc.).

- General Economy (i.e., coinbase©, shopify©, PayPal©, Moonpay© etc.), for Crypto Wallets & Access (i.e., METAMASK©, Fortmatic©, EXODUS©, TREZOR© etc.) and for Marketplaces (i.e., DMarket©, BINANCE©, coinbase©, OpenSea© etc.).
- Music & Entertainment (i.e., VRJAM©, wave©, PIXELYNX©, ZWIFT© etc.).
- Avatar & Interoperability (i.e., CRYPTOAVATARS©, Tafi©, Crucible© etc.).
- Digital Fashion & Identity (i.e., PLACEBO©, Tribute©, Drest©, DIGITALAX© etc.).
- User Interface & Immersion (i.e., APPLE®, Google®, Meta®, XBOX®, SAMSUNG® etc.).
- Visualization & Digital Twin (i.e., unity©, KeyShot©, ENGAGE©, NIANTIC© etc.).
- Development & Infrastructure Tools (i.e., Roll©, Unlock©, Xverse© etc.).
- Cloud, Scalability & Storage (i.e., AWS®, Intel®, GoogleClood®, IBM® etc.).
- Connectivity (i.e., NOKIA®, ERICSSON®, Verizon® etc.).
- Decentralized Infrastructure (i.e., Polkadot©, Flow©, WAX© (layer 1s) and ParaState©, Polygon©, STARKWARE© (layer 2s) etc.).
- Artificial Intelligence (i.e., NVIDIA®, OpenAI® etc.).
- Marketing (i.e., HOTPLAY®, Adverty®, Frameplay® etc.).

It is predicted that the metaverse market will experience growth in the forthcoming years. Several sources have forecasted that metaverse will yield annual revenue surpassing USD 1 trillion [34]. According to Zion Market Research [35], the metaverse industry is expected to grow at a compound annual growth rate of 39.5% from 2022 to 2028. Statista [36] projects the metaverse market for 2030 across three scenarios: conservative (USD 1.91 trillion); moderate (USD 3.17 trillion); and optimistic (USD 4.44 trillion). In light of the ongoing expansion of metaverse, an escalating number of businesses are actively engaging in this ecosystem, fostering value generation for both the vendors and the users.

3. Research Methodology

This section contains the focus group research methodology that was utilized in this article in its attempt to answer the grounded research questions. This methodology applies the focus group discussions, which are widely employed as a qualitative strategy to comprehend social topics in depth that can be used to explore new areas or research issues or to investigate the current ones from the perspectives of research participants [37]. More specifically, this article is based on the discussions that were organized and took place at the focus group on metaverse (FG-MV), which was set up by the International Telecommunication Union (ITU) [6]. The FG-MV was established under the Telecommunication Standardization Advisory Group (TSAG) on 16 December 2022, and was synthesized by experts from all over the world, who voluntarily participated after a broad and inclusive invitation. The formation and works of the focus group were disseminated to the entire membership of ITU, with registration accessible to any interested party willing to actively contribute. In terms of expertise, indicatively, WG7 includes experts in strategy, innovation and digital business, strategic planning advisors, managing experts, experts with broad experience in digitization initiatives, and experts with great experience in international standardization activities. The experts participated in meetings conventionally conducted in person, yet consistently offered the option of remote participation.

By building a community of experts and practitioners and by providing a platform for dialogue, the objective of the FG-MV was to formulate technical reports and technical specifications addressing diverse aspects of metaverse. According to the Terms of Reference (ToR), the FG-MV aimed to support activities such as studying terminology, concepts, vision, use cases and ecosystem, to determine and study the enabling technologies, their evolution and key tasks for standardization purposes, including networking infrastructure, connectivity, interoperability, security, protection of personally identifiable information (PII), digital assets, accessibility and digital twins, to conduct a gap analysis of standardization activities in other standardization bodies, and to examine economic aspects, regulatory implications and environmental sustainability, with the purpose of yielding advantages not only to the ITU standardization scene but rather extending to the broader global community [38]. The lifecycle of the FG-MV was one year, starting in March

2023 until March 2024, and when this article was written, received a six-month extension to July 2024. The extension of FG-MV's activities does not, however, affect this article since the documents relied on have already been approved. The structure of the FG-MV included nine (9) distinct working groups (WG). Each WG explored a specific domain of metaverse, orchestrated individualized meetings, and subsequently communicated its findings during the focus group meetings. To allocate the requisite tasks necessary for the fulfillment of the WG's project, a WG could be further divided into task groups (TG). The WGs that were formed are the following [6]:

- WG1—General
- WG2—Applications & Services
- WG3—Architecture & Infrastructure
- WG4—Virtual/Real World Integration
- WG5—Interoperability
- WG6—Security, Data & Personally identifiable information (PII) Protection
- WG7—Economic, regulatory & competition aspects
- WG8—Sustainability, Accessibility & Inclusion
- WG9—Collaboration

According to the ToR of WG7, its tasks and deliverables addressed economic aspects and competition, metaverse value chain, impacts on revenues and investments, main competitive dynamics: scale and scope economies, metaverse potential market failures and regulatory remedies, and public sector value models. In this regard, its work was completely relevant to the scope of this article.

WG7 coordinated several e-meetings, wherein experts from an extensive number of countries around the world were actively engaged (Table 1).

Table 1. Progress of WG7.

Number of Meeting	Meeting Date	Number of Participants	Participants' Countries
Meeting 1	12 April 2023	16	Brazil, United Arab Emirates, Egypt, Singapore, Spain, Japan, Greece, China, United States, Switzerland
Meeting 2	25 May 2023	20	Brazil, United Arab Emirates, Egypt, Switzerland, Korea (Rep. of), Germany, Tanzania, Portugal, Luxembourg, Nigeria, Morocco, China, Malaysia, Greece, Spain, United States
Meeting 3	14 September 2023	11	Brazil, United Arab Emirates, Egypt, United Kingdom, United States, Switzerland
Meeting 4	16 November 2023	13	United Arab Emirates, Brazil, Germany, Slovakia, Japan, Greece, Egypt, United States, Nigeria, Switzerland
Meeting 5	17 January 2024	N/A	N/A

Participants could submit their proposals (contributions) prior to the scheduled meetings, fostering subsequent discussion and receiving feedback from the other participants during the meeting, trying to disseminate knowledge and exchange of best practices. The meetings were conducted under the guidance of the WG chairmen and vice-chairmen, who were appointed by the FG-MV to maintain the consistent functioning of the WG.

In the inaugural meeting of WG7, the authors presented their contribution, entitled "Defining the business ecosystem and the value sources of metaverse". The purpose of

this document was to advocate for the development of a technical report that will define the business ecosystem and the value sources of metaverse and particularly, to examine how metaverse can generate economic value for businesses and consumers, social value to citizens, and public values that entail citizen engagement and governmental efficiency. Subsequent to the presentation, a deliberative discussion took place and the experts concurred with the findings expounded in this article. Furthermore, they proposed that this contribution could serve as a preliminary framework for forthcoming developments. Regarding the value creation in metaverse, the viewpoint of experts was that metaverse possesses the capability to engender value, with an emphasis on opportunities for economic, public, and social value.

3.1. Results

3.1.1. Industrial Sector

Metaverse fosters economic value generation, notably accentuating avenues for value generation in sectors including manufacturing, tourism, healthcare, and transportation.

In the realm of manufacturing, through the interaction of IoT, AI, digital twins, and other technologies, metaverse may be deployed in factories for the purposes of research and development, production, and operation and maintenance. Enhanced collaboration between designers and stakeholders at the research and development stage can be facilitated through the integration of metaverse. In the manufacturing process, metaverse can assist industrial facilities in monitoring and optimizing production processes, leveraging the technology of digital twins. Additionally, it can enhance security and enable collaborative efforts, overcoming geographical restrictions. Regarding operation and maintenance, metaverse technologies can proactively detect and rectify risks prior to their appearance.

In the field of tourism, metaverse serves as an emerging digital realm facilitating travelers to engage with others and experience places that they have not yet visited physically. Within metaverse, users have access to virtual representations of real-world locations including museums, landmarks, and various tourist attractions. Metaverse proficiently amalgamates virtual and tangible reality, utilizing a variety of digital technologies (i.e., AR, VR) to enable users to move between virtuality and reality and thus, providing immersive experiences.

Moreover, metaverse plays a crucial role in healthcare, notably including telemedicine and distant training for medical professionals. Irrespective of geographic location, learners are able to gain substantial experiences through training simulations like surgeries performed on virtual patients. According to Forbes [39], more than 90% of healthcare facilities will be able to provide patients with remote consultations by 2020. Furthermore, a three-dimensional virtual environment has the potential to optimize treatment efficiency as it allows healthcare professionals to establish effective communication with their patients.

Metaverse finds application within the transportation domain through providing drivers and passengers with an entirely immersive experience. Also, metaverse can provide platforms for monitoring and controlling transportation systems. Utilizing digital twins of physical infrastructure coupled with AI automation, metaverse can engender a more intelligent, efficient, and sustainable transportation network.

3.1.2. Commercial Sector

As consumers are looking for holistic shopping experiences, the immersive nature of metaverse can effectively captivate them. Customers have the capability to engage with metaverse from the comfort of their homes and access tailored and personalized experiences. Although metaverse is still in its nascent stages, it presents the prospect that one day people will be able to work, play, shop, and play games within its virtual realm, eliminating the necessity of leaving their premises [40].

Additionally, metaverse can enrich the customer experience in numerous ways. In the real world, consumers are usually only aware of the final product they buy, without access to in-depth information. Conversely, metaverse can provide consumers with knowledge

concerning the origins of the products by monitoring the manufacturing process. Enabling, thus, a thorough familiarization with the products of interest. Diverging from traditional e-commerce, wherein consumers buy existing physical products, metaverse introduces to consumers a blended experience, encompassing both physical and virtual dimensions. Through the utilization of digital twin technology, products, individuals, and shops can be represented virtually, augmenting the shopping experience. Finally, the interaction between consumers and enterprises can progress to a more substantial level, through AI-powered bots called "digital humans", capable of communicating with users within virtual environments [41]. Beyond the aforementioned, metaverse can provide consumers with an entirely novel experience, as it allows for the digital production of products that don't exist in the real world such as virtual assets, virtual events, virtual clothes, etc. "Gen Z and the Metaverse", a study by Nokia and Ipsos [42], refers that consumer value in metaverse is subject to variability, due to the diversity of consumer requirements and needs. Using data from Accenture Consumer Metaverse Study in 2023 (Insights from ~9000 global consumers), 61% of consumers look forward to interacting with family and friends in metaverse, 52% of consumers expect that metaverse will fortify connections with their favorite brand and 51% of consumers anticipate to create and monetize content in metaverse [43].

3.1.3. Public Values of Metaverse

Metaverse presents an opportunity for citizens to engage with their local governance structures. By participating in social and economic activities as well as in municipal planning procedures within a simulated environment, citizen involvement can be increased. Moreover, metaverse can improve urban design, optimize operational efficiency, help manage energy consumption, and fortify resilience against disasters, by providing operational services through simulation, prediction, and optimization [44]. It might even induce changes in the forms of governance by introducing more participatory procedures. Finally, metaverse is anticipated to improve cities' efficiency, as well as to enrich citizens' interactions and foster innovative virtual experiences.

Although metaverse is still in its early stages, several cities worldwide have already launched their metaverse plans. It is estimated that by 2030, about 700 cities will have some metaverse infrastructure [45]. Dubai initiated its metaverse strategy in July 2023 with aspirations to become a prominent economic force within metaverse. By 2030, metaverse is predicted to increase the country's gross domestic product (GDP) by USD 4 billion and create 40,000 new jobs [46]. According to the Ministry of Science and Information and Communications Technology of the Republic of Korea, the country will spend at least USD 186.7 million to create its metaverse ecosystem, with the potential to create 1.5 million job opportunities [47]. The world's first urban metaverse application, "Metaverse Seoul", is currently available for download by Seoul residents. An integrated platform, "Metaverse Seoul" serves a number of functions, including civil affairs, education, administration, taxation, and cultural tourism. In 2024, Seoul intends to expand the platform's offerings by adding new services, such as facilitating the connection between domestic businesses and overseas investors. The final goal is to integrate virtual and augmented reality technology into the daily operations of the city's infrastructure [45]. Furthermore, Barbados plans to launch the first metaverse embassy. The Barbadian Ministry of Foreign Affairs and Foreign Trade signed an agreement with Decentraland [48], a platform offering a fully digital environment, for the establishment of the metaverse embassy. With the release of the embassy, Barbados will become the first country in the world to recognize digital sovereign land [49]. Santa Monica is the first city in the US to have access to metaverse through application. "FlickPlay" is a social media application integrating NFTs to create augmented reality films by unlocking digital tokens in the real world. Founded by Pierina Merino, the application is credited with reducing crime rates in Santa Monica by activating unused city spaces with art. Users search real-world areas for unique digital tokens that unlock videos featuring uncommon filters. Through stimulating activity in less-trafficked urban areas,

"FlickPlay" reduces crime and promotes economic growth [45]. Ultimately, the European Commission attempts to cultivate metaverse from three perspectives: people, technologies, and infrastructure. This new virtual environment must be centered on Europe's values and rules. To master metaverse technologies, Europe is building an ecosystem based on the existing capabilities of emerging technologies. Finally, a more resilient connectivity infrastructure is anticipated to be instrumental in shaping metaverse [50].

3.1.4. Social Values of Metaverse

In the past decades, a notable transformation in social activities has occurred. The proliferation of digital technologies, particularly the integration of social media platforms, has broadened our understanding of interpersonal communication. They help facilitate the resolution of certain obstacles, such as geographical distance and language barriers. Metaverse can further enhance social interactions, fostering more immersive and participatory experiences that closely mimic real-world interactions.

Leveraging technologies such as digital twins, AR, and VR, enhancements are observable in various domains such as employment, gaming, commerce, education, and entertainment.

Throughout the COVID-19 pandemic, there was widespread adoption of remote work on a global scale. There has been a significant increase in the number of individuals participating in remote work, and according to Forbes [51], by 2025, it is predicted that 70% of the workforce would spend at least five days a month working remotely. Remote work, on the one hand, has the potential to simplify the professional lives of workers and amplify their efficiency. On the other hand, it may lead to a lack of in-person collaboration, body language communication, etc. that are typically found in traditional workplace environments. The implementation of metaverse stands to improve the remote work experience as it can offer a virtual space conducive to meetings and collaboration among colleagues characterized by immersion. According to Ball [1], virtual meetings in metaverse are more effective than video calls, reflecting the real work environment and the actual facial expressions.

The concept of metaverse has been embraced by the video game industry for numerous decades. Several gaming companies, including Epic Games [52], Roblox [53], Axie Infinity [54], Decentraland [48], Sandbox [55], etc., have been progressively transitioning towards metaverse, offering players a more interactive gaming experience with the use of AR, VR, cloud computing, and other digital technologies.

In the context of shopping, metaverse holds promise for delivering innovative and immersive shopping experiences to customers. It enables the provision of 360-degree perspectives of virtual showrooms, where customers and models are depicted through avatars—digital representations of people. Liu et al. [56] compared the ability of 360-degree videos to evoke four different emotional states when viewed on 2D computer screens against VR head-mounted displays. Their study provides actual evidence that "high-arousal positive emotion evoking is more effective in VR than on a 2D monitor based on computational affection". Numerous enterprises are establishing virtual stores in metaverse, such as Adidas, Burberry, Gucci, Nike, Samsung, etc. Furthermore, Non-Fungible Tokens (NFTs—a type of digital content that can include music, art, videos, etc.) can also escalate the shopping experience by providing an exclusive digital identification distinguished by its uniqueness and irreplaceability.

Metaverse presents opportunities for educational transformation, incorporating VR and other digital technologies, altering the traditional teach-and-learn processes. It can offer immersive interactive experiences, facilitate the visualization and simulation of abstract theories, and foster personalized learning environments. In addition, by mitigating learning costs and associated risks, metaverse has the potential to foster equality in educational accessibility for citizens across both developed and developing countries. According to a PWC's survey, learners utilizing VR technologies exhibited a learning acceleration four times greater compared to a traditional classroom [57].

An additional application of metaverse concerns virtual performances and events. Metaverse facilitates the hosting of various types of events, such as music concerts, festivals, trade shows, fashion shows, etc. Its immersive nature and its extendable features offer an expansive virtual space capable of accommodating an extensive variety of events. Many enterprises have already conducted numerous events within metaverse. A notable metaverse event in 2022 was Decentraland's Metaverse Fashion Week (MVFW), drawing in 108,000 unique visitors over its five-day operation from 24 to 27 March. During this event, several activities took place, including virtual store openings, fashion shows, and afterparties. According to data released by Decentraland, the event saw the purchase of 7065 wearables sourced from various designers, the minting of 165,861 free wearables, and the sale of wearables totaling 76,757 dollars [58].

3.1.5. Sustainability of Metaverse

Today, the evolution of technologies such as AI, digital twins, IoT, 5G connectivity, and blockchain have contributed substantially to the development of metaverse. It is argued that metaverse could yield significant implications for environmental, economic, and social sustainability while concurrently metaverse can introduce a multitude of potential risks (Table 2).

Table 2. Environmental, economic, and social sustainability of metaverse.

Sustainability of Metaverse		
Approaches	**Opportunities**	**Risks**
Environmental	• Enhancement of energy efficiency • Emissions mitigation • Reduction of material consumption	• High energy consumption
Economic	• Economic advancement for businesses: ➢ new business ecosystem ➢ virtual stores ➢ expansion of product lines ➢ enhance their operational efficiency • Economic advancement for people: ➢ employment opportunities ➢ enhancing shopping experiences	• For businesses: ➢ increase of power inequalities • For people: ➢ over-consumption
Social	• Optimization of communication • Enhancement of educational processes	• Social exclusion • Health-related complications • Security and privacy

Environmental Aspect

With regard to the environmental impact associated with metaverse, it is argued that, on the one hand, metaverse can mitigate physical mobility, thereby diminishing the energy consumption correlated with such activities. Metaverse platforms provide virtual environments mirroring physical ones where people are capable of engaging in diverse activities, such as work, education and training, entertainment, and social interaction. Consequently, this minimizes the imperative for physical mobility, and, by extension, reduces carbon emissions.

Furthermore, through the utilization of digital twin technology, it is anticipated that metaverse will enhance energy efficiency and facilitate emissions mitigation within the industrial sector. To exemplify, Renault Group has launched the first industrial metaverse ambition. It is estimated that, by 2025, it will generate a 50% reduction in the carbon footprint of its vehicle manufacturing [59]. In light of cities being responsible for more than 70% of the yearly carbon emissions worldwide [60], metaverse holds the potential to help cities optimize their resources utilization. Through the use of digital twin technology,

metaverse can help improve the efficiency of building operation and maintenance, and can also help reduce traffic congestion [61]. Moreover, metaverse can contribute to carbon neutrality by replacing physical goods with virtual equivalents [62]. According to Forbes [63], metaverse has started to promote sustainability, and it has the capacity to revolutionize material consumption. Presently, there is an emergent community of consumers who derive satisfaction from acquiring digital assets in metaverse. Despite the considerable energy consumption associated with the production of digital goods, it pales when contrasted with the global supply chain resources, consumption, and wasteful disposal of physical goods.

On the other hand, a high-energy-consuming metaverse may reverse the positive impacts of renewable energy sources. While metaverse aids in mitigating the carbon footprint, its sustainable nature remains questionable due to the substantial energy consumption required for its operation.

Considering the massive amount of computing power inherent in metaverse technologies, metaverse could amplify the carbon footprint [64]. Metaverse requires continuous expansion of the computing infrastructure, resulting in increased energy consumption [65]. Beyond the energy consumed for its operation, metaverse necessitates the use of new devices to enable its functionality, such as virtual reality headsets, augmented reality glasses, and sensors [66]. Despite that metaverse presents numerous prospects for environmental sustainability, it is essential to minimize its detrimental environmental outcomes in order to ensure its sustainable development.

Economic Aspect

The economic sustainability of metaverse is underpinned by the establishment of an entirely new business ecosystem that offers many opportunities for economic development. Amidst this emerging ecosystem, companies have the opportunity to establish virtual stores within which they can sell their products and services to avatars. In this way, they can offer new and more immersive shopping experiences to their customers, augmenting customer value. In addition to the possibility of selling their products in virtual markets, within this ecosystem, companies have the capacity to expand their product lines by developing a variety of digital products for sale. As a result, they can create new purchasing experiences for customers and subsequently foster sales growth [67]. Furthermore, metaverse, in addition to being deployed for research and development, production, operation and maintenance purposes, as mentioned above, possesses the potential to improve production management. Through the utilization of digital technologies, metaverse can enable prospective buyers to virtually test products prior to purchase [68], thus leading to waste minimization. Finally, metaverse can alter the nature of employment. By promoting remote work and overcoming geographical and temporal constraints [69], it introduces an entirely new dimension to economic activities, broadening the employment prospects.

Although metaverse can generate considerable economic values, there is the possibility of inducing over-consumption among its users [70]. With an abundance of shopping opportunities and the enhanced shopping experiences within metaverse, consumers may exhibit tendencies towards over-consumption. Furthermore, the implementation of metaverse necessitates considerable resources, specialized knowledge, collaborative efforts, and innovative approaches. Consequently, metaverse could exacerbate power inequalities among developed and developing regions, rural and urban areas, and enterprises of various scales, taking into account their differing degrees of specialization. As a consequence, it is crucial to secure widespread accessibility and affordability of the fundamental infrastructure of metaverse, thereby fostering economic and societal advancement [70].

Social Aspect

The most essential concepts underpinning the social sustainability of metaverse include the optimization of communication alongside the enhancement of educational processes. According to Hennig-Thurau et al. [71], metaverse predominantly facilitates social interactions within the digital realm, despite the notable reduction of real-world social inter-

actions. Endowed with the capacity to provide improved realism and presence, metaverse is presented as a platform that fosters the satisfaction of social needs, especially among young people. Diverging from traditional social media platforms that rely on textual, auditory, and visual content creation, metaverse can offer increased realism in communication [72]. In addition, the study conducted by Oh et al. [72] highlights the potential that metaverse can boost social self-efficacy. Allowing users to practice social interactions within a secure virtual environment, metaverse can serve as an essential starting point for cultivating social skills and fortifying social confidence. As mentioned by Locurcio [73], metaverse can reshape education by furnishing more participatory and dynamic learning experiences, accommodating diverse learning styles, contingent upon learners' needs [74]. Moreover, metaverse can afford activities which are challenging or unattainable within the real world such as conducting experiments and simulations. In this way, metaverse gives students the opportunity to become familiar with and immerse themselves in scientific phenomena and historical events, increasing in-depth understanding [75]. Finally, metaverse has the potential to facilitate the global dissemination of education irrespective of the economic status or the geographic location of learners, especially in areas where educational accessibility is constrained. Through the establishment of a global learning community, metaverse is expected to provide stimulating experiences and collaboration among students worldwide, effectively breaking down barriers related to language, socio-economic status, geographic location, and cultural differences [66].

Conversely, societal concerns such as social exclusion and discrimination that are evident in the real world can be amplified within the virtual realm of metaverse. Since joining metaverse requires the use of technological devices, there is a high probability that certain groups of the population, which lack the necessary conditions—financial, age-related, educational, or skill-dependent—may be excluded from metaverse. Hence, there is uncertainty regarding metaverse's ability to serve the global society simultaneously or uniformly [76]. Furthermore, involvement with metaverse can cause health-related complications for its users. According to Griffiths et al. [77], engagement in online activities such as gaming, e-commerce, and social networking platforms can trigger behavioral addictions. The most addictive element of media lies in their ability to replicate reality [78]. Metaverse is about to become the most realistic form of media so far, and thus the most exciting medium. Moreover, metaverse offers individuals the potential to create, within a parallel universe, a secondary reality distinct from their primary existence. A secondary life which is different in terms of their physical representation—giving their avatars a completely different form than their real one, in terms of their financial status—wealth creation is possible through the possession of multiple digital currencies that lack tangible real equivalents, as well as in terms of sociality—people who abstain from physical social gatherings, may become significantly involved in virtual social interactions. Engaging in a parallel existence, distinct from the real one, can pose a significant threat to mental stability. According to Usmani et al. [79], the phenomenon 'Proteus effect' which claims that people who invest a significant amount of time and effort in shaping their virtual identity tend to adopt characteristics of their digital character, and thereby leading to changes in their behavior in the real world, appears to be present within metaverse, potentially disrupting their mental stability. Finally, according to Liu et al. [80], in an immersive virtual environment, visual stimuli have a markedly different effect on human perception and behavior than they do in the actual world. The experiment they conducted showed that the correlation between emotional states and the value of visual stimuli influences human attentional bias.

Wang et al. [81] have pinpointed various security threats for users within metaverse systems, encompassing concerns related to authentication and access control, privacy, network, economy, physical/social effects, and governance. These threats demonstrate the complexity and versatile nature of security challenges within virtual environments. Moreover, Dwivedi et al. [82] while focusing on security and privacy in metaverse, highlight issues concerning data security, users' privacy, and Software–Hardware–Network security.

The avatar generates diverse data encompassing private information such as voice, video, and messages, which are stored in virtual environments. Therefore, there exists the risk that these data could be falsified and leaked. Furthermore, compared to traditional systems, metaverse has the capacity to gather substantially more sensitive data such as eye-tracking, which can seriously compromise user privacy. Moreover, security threats such as insecure system architecture, unpatched software, and malware that exist in other software systems are also present in metaverse. Using the security vulnerabilities of metaverse devices (VR headsets, IoT devices, etc.), attackers can remotely handle the linked devices and take control of certain device data. Finally, metaverse platforms typically lack encryption for network connections, leaving data vulnerable to interception by attackers through sniffing or spoofing attacks. The Technical Report ITU FGMV-10 [83] recognizes the potential harms of these threats. Security issues, which include identity theft and fraud, malware and viruses, data breaches and leaks, and cyberattacks, are serious challenges in metaverse. Cybercriminals can target avatars created with biometric data, which could lead to identity theft. Furthermore, malware designed specifically for metaverse exploits vulnerabilities in virtual platforms to allow threat actors to take over users' devices and compromise data. Sensitive information is made public by data breaches, which enables disruptive attacks. In order to mitigate cyber threats and protect user privacy, comprehensive solutions are needed to handle these security issues as the metaverse evolves.

3.1.6. FG-MV Related Deliverables

In the scope of FG-MV, WG7, within the framework of its objectives, has presented two Technical Reports [84,85] concerning the regulatory aspects of metaverse. According to the first one [84], ensuring an inclusive metaverse requires addressing the digital gap and environmental concerns while promoting standards and interoperability. Furthermore, privacy, security, and ethical frameworks that align with societal values are crucial. For sustainable development, policies related to metaverse and its enabling technologies must be coordinated. The second Technical Report [85] is structured into two sections: general data protection concerns and economic data protection concerns. It introduces the "Life Cycle of Data Threat Model" which identifies threats at various stages of data handling: data generation, transfer, usage, sharing, storage, archival, and destruction. Key data protection and privacy concerns include complex roles, data sharing, expanded data sources, mass profiling, proliferation of harmful content, avatar identity issues, intellectual property rights, and data sharing for investigations. Furthermore, economic activities in metaverse present regulatory issues concerning trademarks, trade secrets, and delineating the relationship between virtual and real-world goods. Finally, the Report proposes a data protection assessment framework to evaluate these challenges and prioritize policy actions accordingly.

As far as sustainability is concerned, according to the ToR of WG8, its tasks and deliverables addressed impact on the climate changes, environmental sustainability and circular economy related issues, diversity, equity and inclusion, social considerations, and accessibility related issues. The WG was divided into 4 Task Groups so that each of them could specialize in exploring a specific topic. The TGs that were formed are TG—sustainability, TG—accessibility & inclusion, TG—sustainable metaverse design, and TG—metaverse social safety. Among the deliverables presented in and approved by the FG-MV were the Technical Report ITU FGMV-08 [86] and the Technical Specification ITU FGMV-16 [87]. The first one, entitled "Design criteria and technical requirements for sustainable metaverse ecosystems" outlines the technological specifications and design standards essential to build metaverse ecosystems that are environmentally, socially, and economically sustainable. It also summarizes the general requirements for the design of sustainable metaverse ecosystems, ensuring that it complies with moral standards. A sustainable metaverse ecosystem must adhere to ethical principles rooted in human values and adopt responsible design practices following the tech-responsible design approach. Resource efficiency and proportionality form the foundational principles of technological sustainability. Finally,

this paper proposes design criteria for energy-efficiency and their technical requirements from three aspects, Energy-efficiency & environmental aspects, Human-centric design, and Community & economic growth. The second one, entitled "Accessibility in a sustainable metaverse" examines the social benefits and environmental effects of integrating accessible goods and services into a sustainable and energy efficient metaverse. Moreover, it provides recommendations on how to integrate sustainable accessible goods and services into metaverse. When developing a sustainable and accessible metaverse, several factors need consideration. These include making usability and accessibility by default, minimizing content duplication, designing a cleaner interface, prioritizing icon-based navigation, optimizing energy usage, exploring alternative file formats, enhancing AI energy efficiency, and incorporating intuitive design with easy-to-understand language options.

4. Conclusions

This article endeavored to delineate the intrinsic values generated by metaverse and to elucidate their implications on human existence. In particular, this article posited three research questions aimed at delving into these objectives.

Regarding the first research question (RQ1) and the spectrum of values that may arise from metaverse, several opportunities for economic, public, and social value generation were identified, verifying the hypothesis whether metaverse can generate economic, public, and social value (H1). The economic value concerns both the industrial and the consumer sectors. Most opportunities are extended to sectors like manufacturing, tourism, healthcare, and transportation. From the commercial perspective, metaverse can enrich the consumer shopping experiences via furnishing immersive services. From the citizens' standpoint, metaverse can amplify citizen participation in social and economic activities, and engagement in government decision making. In addition, metaverse is anticipated to enhance cities' efficiency and urban design. Finally, metaverse is expected to affect social activities too and generate social values like new employment opportunities, new gaming experiences, new commercial services, new education methods, and virtual events, which will all provide users with enhanced immersive and participatory experiences.

Regarding the second research question (RQ2) and the underlying hypothesis that metaverse can bring about changes in people's daily lives (H2), it was highlighted that metaverse will revolutionize people's lives through the generation of the aforementioned values. In light of the opportunities that are enabled by metaverse, the economic, public, and social status of real life are expected to be reshaped. More specifically, the emergence of metaverse will inaugurate new avenues for economic activities, facilitate socialization, and enhance citizen empowerment.

Finally, in sustainability terms that were addressed by (RQ3), this paper uncovered opportunities and threats for environmental, economic, and social sustainability, confirming the hypothesis whether the generated values can affect environmental, economic, and social sustainability (H3). Concerning environmental implications, metaverse capacity to ameliorate energy consumption is evident through the mitigation of physical mobility to remote participation and the resource utilization. In the realm of economic viability, metaverse fosters economic advancement for both businesses and people. Enterprises can launch virtual stores, expand their product lines to digital products' delivery, and can enhance their operational efficiency. From the people's perspective, metaverse can offer new employment opportunities and elevate consumer satisfaction by enhancing shopping experiences, even with the potential of over-consumption. Finally, the fundamental principles underlying the social sustainability of metaverse involve the optimization of communication and the enrichment of educational processes. Metaverse can facilitate social interactions and offer more participative and dynamic learning experiences, overcoming barriers linked to language, socio-economic status, geographic location, and cultural diversity. On the contrary, threats such as social marginalization, prejudice, health-related complications, and security concerns could be amplified by metaverse. Despite the opportunities it presents

for reducing the carbon footprint, metaverse entails substantial energy demand raising questions relating to its energy efficiency.

This article outlines the inherent values produced by metaverse and clarifies how they affect human existence. This study also identified risks and opportunities for social, economic, and environmental sustainability. However, a limitation arises from the current nascent stage of metaverse, as its adoption remains relatively limited. The values and impacts of metaverse on both people and sustainability will become apparent when metaverse begins to be widely used. A further limitation arises from the fact that the experts participated in WG7 come from a relatively limited number of countries. Finally, despite the fact that the FG-MV is still ongoing, the documents relied on this article have already been approved. Some future thoughts regarding this article center on the imperative for validation of these findings when metaverse expands. In this regard, further research is needed in order to verify or disprove these findings.

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