From Pixels to Planet: Toward Sustainable Practices in the Metaverse

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Abstract

Development has two sides: it creates solutions for the now while losing sight of the future. It is progressive and motivated by the need for time. Numerous historical examples, such as the Industrial Revolution, support this claim. Technological innovation is currently needed for sustainable development; thus, anytime a new technological advancement is made, a critical social discussion is sparked to determine both the advantages and disadvantages of innovation for sustainable development. The newest and most talked-about innovation, called the metaverse, is still in its infancy and combines the ideas of many people. Discourse analysis on "sustainability and metaverse" was employed in this study to gather various viewpoints and carry out exploratory research. Through thematic content analysis, various themes were identified and categorized into two groups, highlighting the "metaverse as a solution" and "metaverse as a problem." Making this technological innovation a solution will require built-in sustainability within and outside the metaverse. Creating a more inclusive, equitable, and diverse metaverse can be achieved through re-imagination and transforming the collaborative workspace by putting sustainability first. Building sustainability into the front end of the virtual world rather than retrofitting it after exponential growth.

Key Words: *Metaverse, Sustainability, Energy Consumption, Innovation.*

1.0 INTRODUCTION

We are on the cusp of revolutionary technological innovation- the metaverse (Bianzino, 2022). The metaverse is a virtual shared space, fully immersive, self-sustaining, and hyper spatiotemporal for the adaptive use of humans to socialize, play, and work (Wang et al., 2022). The virtual world of the metaverse is the confluence of many technologies like artificial intelligence, extended reality, blockchain, IoT, and 5G/6G. The concept of the metaverse is truly fascinating. It is not just about being on the edge of a digital world but rather the idea of fully immersing oneself in a digital world through avatars and VR technology. This allows for a truly immersive experience where one can touch and feel within the digital realm. It is exciting to think about the possibilities and potential the metaverse holds for the future. Metaverse is like the actualization of any science fiction movie in the digital world.

Technologies powering the metaverse are advancing, and so is the formation of the metaverse. The pandemic has shown us how to do things differently, but the metaverse is expected to change our behavior and attitude toward doing things differently. It will change our existing way of traveling, educating, meeting, entertaining, producing, and consuming. The metaverse will allow the free emanation of knowledge, virtual meetings and gatherings, consumption of virtual assets rather than physical ones, and city planning through replicating ideal digital twins in the real world, simultaneously curbing carbon emissions and waste due to all these activities. Achieving this believable metaverse requires a boost in computing power, real-time low-latency networks, geographically distributed data centers, and evolving technologies. The inoperability to run multiple metaverse with a seamless transition will also necessitate standards and regulations (Farboschi, 2022).

Despite this, we must recognize the flip side of the metaverse because of the careless attitude adopted in digital transformation so far (De Giovanni, 2023). All the technologies and advancements involved are energy-consuming and carbon-emitting. The average energy consumption by a single Ethereum transaction is 60% more than 100,000 credit card transactions, while the energy consumption of an average Bitcoin transaction is 14 times more. The CO2 produced by the average NFT transaction is 48 kg, equivalent to the CO2 produced by approximately 18 liters of diesel (Bianzino, 2022). As per researchers at the University of Massachusetts, Amherst, 626,000 carbon emissions happen while training AI robots (Hao, 2019). If these figures are less threatening, the metaverse requires a large amount of data

and advanced computing because every individual, object, and environment has to have a digital twin in the metaverse. It also requires a low-latency (close to users) network and data centers to give them a seamless interaction experience. Data centers themselves consume a lot of energy.

Every technology also has socio-economic ramifications, including those related to privacy, security, accessibility, diversity and inclusion, ethics, and regulation. If the internet and social media are any guide, these natural world social ills have also crept into the digital sphere. At this stage, where the metaverse will go is highly unpredictable. Technological zealous is vouching for its curative abilities to reduce energy consumption, carbon emissions, waste, and mismanagement, as well as increase diversity and inclusion, education, healthcare, etc. However, there are always two sides to a coin; hence, this study relied on views from industry, consultants, and experts to get an insight into the metaverse. For this, the approach adopted is discourse analysis; we searched Google with the words "metaverse and sustainability" and analyzed the content of the fifty-seven websites populated. Through thematic content analysis, we tried to answer the following questions.

RQ1: What are the sustainable issues in forming the metaverse and their possible resolution?
RQ2: What are the social, environmental, and economic issues that can be resolved using the metaverse, and how?

Since the academic literature on the sustainability of the metaverse is in the progressive stage, the present study will contribute to the academic debate of "metaverse or not" from the perspectives of users, developers, contributors, and experts. Hereafter, other sections of this paper include Literature Review in section 2, Methods in section 3, Data in section 4, Analysis and Discussion in section 5, and Conclusion and Societal Implications in section 6, and References in the last section 7.

2.0 LITERATURE REVIEW
Sustainability is not a means to an end but an end that strives to enhance inclusive well-being. Technological innovations provided the means to achieve this end. Innovation is recognized as one of the goals (Goal 9) in the Sustainable Development Goals to be achieved by 2030. Though the phrase Technological Innovation is used synchronously and is fundamental to the concept of sustainable development, both have different domains. Innovation, for its part, can refer to something new or a change made to an existing product, idea, or "process by which technology is conceived, developed, codified, and deployed," whereas technology is the application of scientific knowledge to the practical aims of human life through devices, methods, processes, and practice (Brooks, 1980; Anadon et al., 2016)

The advancements we see today are beyond anything that could have been imagined in the 19th century. Artificial intelligence, robotics, blockchain, and extended reality are making their forays in today's world and expediting human progress. All these technologies, combined with the growth of the internet and Web 3, led to the conceptualization of the metaverse, which existed in fictional worlds only. While walking through the different milestones that led to the conceptualization of the metaverse, Farboschi (2022) explained the seven layers of the metaverse: digital, communication, cloud, virtual cloud, data space, digital twin, and perception. He believes that integrating virtual presence and remote technologies will simulate our behavior and may succeed in eliminating travel and the collection of physical artifacts. However, it will probably take a decade to make this happen on a large scale.

Many researchers also envisioned the metaverse's contribution to urban planning and transportation. Digital twins of cities will model the impact on things and life by changing the city's physical environment due to environmental emissions, traffic congestion, and rising sea levels (Kim & Kim, 2025). Individuals' behavior and interaction with the natural world, as perceived through the digital twin of the individual and the natural world, will be able to redefine the smart cities of the future; however, there is skepticism about social, human, ethical, and cultural concerns in the metaverse (Allam et al., 2022).

The pandemic showed us the possibility of working from home in a digital environment. The metaverse will make this environment more interactive and immersive, similar to physical interaction. This will change the traditional workplace concept, eliminating the need to crowd megacities and reducing

population pressure on megacities (Choi, 2022). Education is another sector where the metaverse will reduce disparity and make it accessible without the constraint of space and time (Sá & Serpa, 2023). The education ecosystem in the metaverse may consist of 1) instructional design and performance technology; 2) knowledge; 3) research and technology; and 4) talent and training (Wang et al., 2022). To make education available in the metaverse environment, Uddin et al. (2025) stressed the need for hands-on teaching and learning opportunities for educators in an emerging technological climate for sustainable education. Keeping learning methodology in sync with the presently active metaverse of gaming, Park & Kim (2022) researched world types providing graceful experiences to learning and identified survival, maze, multi-choice, rock/jump, and escape room as world types for gamefic learning.

The process of product development will also change with the metaverse, as people may articulate their expectations of products and product packaging in the metaverse, reducing time and waste of natural resources. Metaverse also provides opportunities for collaboration and resource sharing (Jianhai et al., 2025). Since consumers are found to be consistent in virtual reality and actual choice behavior (Hadi et al., 2024), the product developed in the metaverse will find consumers in the real world. Fashion, consumers, and real estate will be the biggest beneficiaries of the metaverse by satisfying consumer needs in the virtual world and by reducing environmental impact in designing, production, and supply chain (Yan, 2022; Sayem, 2022). In the metaverse, collaboration and work efficiency may increase in the B2B market, and brands can experiment with immersive experiences for customers to attract and retain them in the B2C market (Kamdoum, 2022).

Technological breakthrough brings as many risks as opportunities (Green et al., 2022); in the metaverse, everything is not so green. The technology behind the metaverse is energy hungry, be it artificial intelligence, blockchain, or extended reality; the infrastructure required to be a part of the metaverse (virtual reality/ augmented reality) needs non-renewable resources in rare metals and water, with a huge carbon footprint. Poor recycling practices and technological obsolescence will put the sustainability of the metaverse in question (Kamdoum, 2022). Storing data requires large data centers; at present, not all data centers are dependent on renewable energy. Apart from environmental concerns, social issues of privacy, safety, trust, misinformation, and application of the law, as well as psychological problems related to addiction and its impact on people, exist in the development of the metaverse (Dwivedi et al., 2022). People have already experienced the effects of these issues in the Internet and web2 age. Security breaches and privacy invasions are inherent in the underlying technology and can arise in the secure provisioning of the metaverse as well (Wang et al., 2022).

Technology is still improving, with a 16.9x increase in internet traffic and 9.4x in data centers, yet energy consumption grew only 1.1x (2) (Bianzino, 2022). If this trend continues, we can envision a sustainable metaverse. Metaverse sustainability can be defined as "the ability of the metaverse to exist and develop without depleting natural resources for the future" (Zhang et al., 2023). The rules for metaverse sustainability are the same as for natural world sustainability. Efforts are on to achieve metaverse sustainability as Ethereum moves from "Proof of Work (PoW)" to "Proof of Stake (PoS)," reducing the energy requirement by 99.6%. Cloud-based data centers with renewable energy sources are options, and world tech giants Microsoft and Google have committed themselves to achieve net-zero emissions targets by 2025 and 2030, respectively. Green software and green technologies are becoming buzzwords.

3.0 METHODS
The research methodology of discourse analysis for examining the subject in hand "by combining the informed narrative and multi-perspective approach from experts and varied disciplinary backgrounds" (Dwivedi et al., 2022) provides a general framework for problem-oriented research (Wodok & Krzyzanowski, 2008). The discourse analysis hypothesizes that "social reality is socially constructed". In the study, researchers used the internet to accumulate different opinions of experts, industry, consultancy, and others on the metaverse and its sustainability aspect. The internet is a medium for all to express their thoughts on varied topics without being stressed about being right all the time. Hence, it has a wide variety of views, positive, negative, and neutral. Because of variation in thought processes, this particular medium has been selected to study emerging thoughts on the metaverse.

In its early stages, the metaverse received much attention for its challenges and potential solutions. The discourses also highlighted the promises that the virtual world offered in addressing real-world issues. We did research on the topic of sustainability in the metaverse. During our search, we came across various sites that had content related to this topic. Interestingly, even though our search was conducted on different dates, we noticed that the same sites appeared in the search results with slight variations in their ranking, which indicates the popularity of the content. The popularity of the term "metaverse" over a period of time is seen through Google Trends and shown in Figure 1. Though popularity is on decline, it is still meaningful.
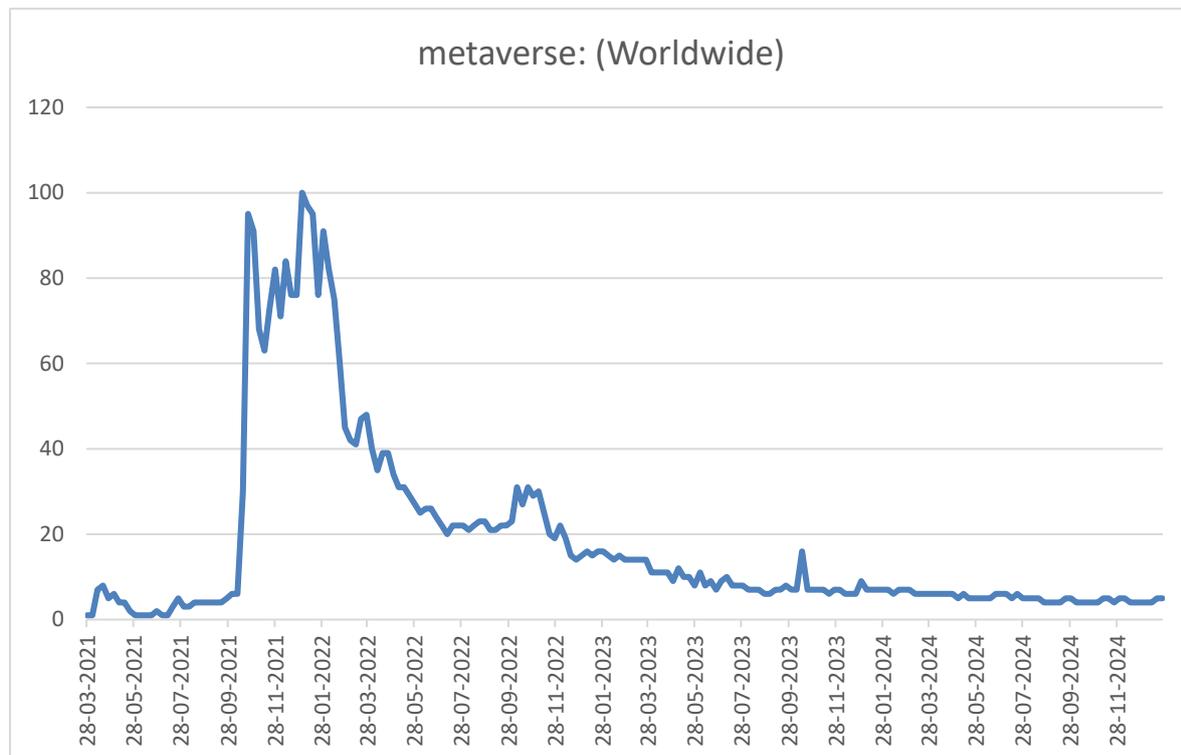

Figure 1: Term "Metaverse" popularity trend for period Mar-21 to Jan-25 (Source: Google Trends)

In the present study, researchers used the thematic content analysis of the fifty-eight sites to gain insights into the sustainability issues plaguing the metaverse and the solutions proposed. In addition, we also examined the themes that emerged, using the metaverse to tackle sustainability issues faced in the physical world. Thematic content derived from discourse analysis is appropriate to seek an understanding of thoughts, behaviors, and experiences (Kiger & Varpio, 2020). The study used the inductive method till the data saturation point, a point where new themes stopped emerging, since this approach helps derive themes from data (Varpio et al., 2020) and provides a broader, more extensive data set analysis. Many authors have utilized Google trend data, as highlighted by Kapoor et al. (2018). However, incorporating diverse perspectives through articles, blogs, podcasts, newscasts, and opinions provides a comprehensive standpoint.

We followed the steps suggested by Braun and Clarke (2006), and after going through the website articles, we created the codes. Data is coded and extracted to develop the themes by revisiting the websites. After careful analysis of the extracted data, themes are developed. The significant disadvantage of thematic content analysis is its flexibility, but for the present study, it is a requirement. Tabulated data shows the codes and correlated themes, while graphs display the quantitative count of themes in website articles.

4.0 Data
Discourses, including the words "Metaverse and Sustainability," were downloaded from Google from November 2024 to April 2025. After coding discourses and inductive analysis of content, themes emerged that divided the discourses into two broad categories. The first category is the discourses that raised the sustainable issues of the metaverse in their content. The second category consists of discourses about

solving real-world sustainable problems through the metaverse. Very often, discourse conveys their perception both ways.

Sustainable Issues in the Metaverse

The codes and themes that emerged during content analysis have been outlined in Table 1.

Codes	Themes	Theme title for graphic display
Energy Consumption	The requirement of an abundance of cloud-based data and blockchain transactions will require enormous energy and eventually increase carbon emissions.	Energy Consumption and Carbon Emissions
Carbon Emissions		
Non-fungible token (NFT)		
Blockchain		
Data Centers and Storage		
Resource use	New hardware requirements, lack of circular economy, and unhealthy competition create e-waste and put pressure on already stressed natural resources.	E-waste
E-Waste		
Privacy	Ethical risks like a lack of data protection, violence between avatars, fake news, etc., may plague the metaverse, as well as the problems that have plagued Web 2.0 since its inception.	Privacy, Security, Trust
Safety/Security		
Trust/ Misinformation/fake news		
Diversity and Inclusion	There is a greater probability of replicating the unsustainable social dimension of the real world into the metaverse and creating a divide between rich and poor regarding accessibility.	Diversity and Inclusion
Physical and Mental Well-being	What if people withdraw from real-life social interactions as they prefer the heightened experience of engaging in the digital world? Cyberbullying is ever-present.	Physical and Mental Well-being
High Cost of Gadgets	New hardware requirements, constant advancement, and high cost make gadgets unaffordable.	High Cost of Gadgets
Commerce	The inoperability of metaverses creates the problem of jurisdiction, conflict, and choice to apply beneficial jurisdiction in different aspects.	Commerce
Legislation	Increased shopping in the metaverse leads to increased blockchain transactions.	Legislation

Table 1- Codes and Sustainable Themes in Metaverse (Compiled by Authors)

Against the above themes, we have collected data from websites citing these themes as a perceptible problem in the metaverse. Since the metaverse is still in the making, it is hard to perceive how it will take shape. Figure 1 shows the number of websites that included these themes in their content-
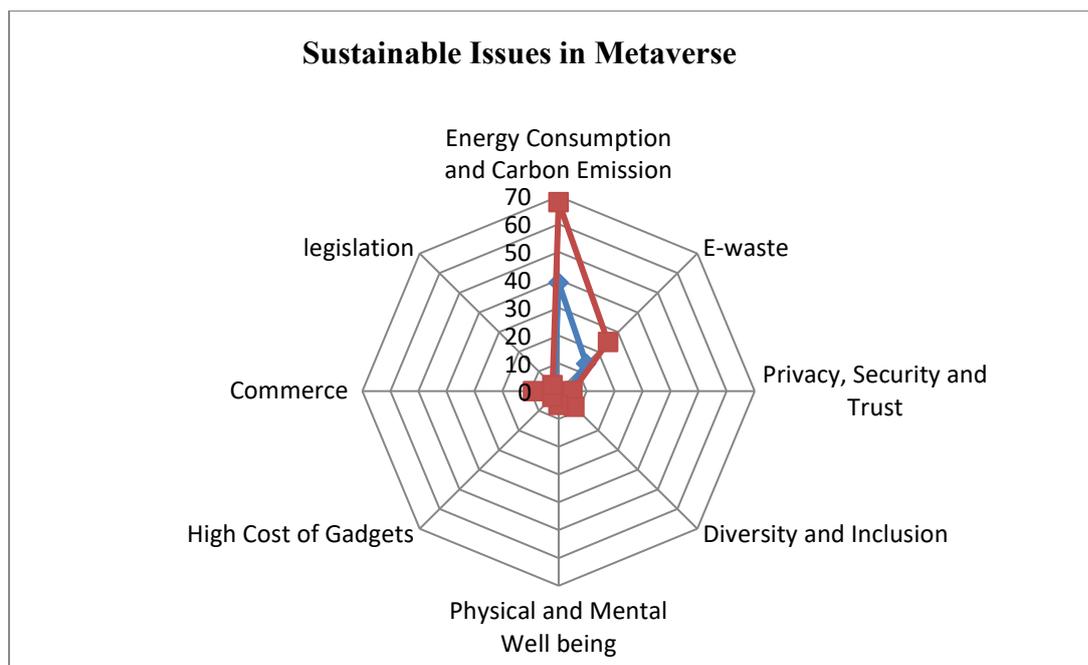
Figure 2: Discourses in percentage with Perspectives on Sustainable Themes on Metaverse (Compiled by authors)

Sustainable Issues of the Real World

The description of themes related to solving the natural world problems in the metaverse is detailed here in Table 2-

Codes	Themes	Theme title for graphic display
Excessive buying	Conspicuous wasteful consumption by people contributes to unsustainable consumption of resources, emissions, and waste generation. E-commerce made shipping and returns easy. Brands produce more than they sell, causing either destruction or discounting of inventory.	Unconscious Consumerism
Consumption of physical assets		
Luxury Brands/Fashion Industry		
Virtual assets		
Climate Condition	The biggest problem in climate change is our behavior, as we are conditioned for the success of " now" rather than long-term success.	Climate Condition
Virtual meetings/ concerts	People make many trips to work, meet, and entertain, causing many carbon emissions from vehicles and transport.	Travel and Tourism Emissions
Virtual tours		
Travel Emissions		
Inaccessibility of education and opportunities	Dissemination of education is not equal, and many people need help to afford quality education in want of money or opportunities available.	Inaccessibility of education and opportunities
City Planning	Buildings are the most significant source of carbon emissions; traffic congestion, municipal problems, and environmental emissions are other issues impacting city planning.	City Planning
Product Development and Processes	Brands invest a lot of money and resources in developing prototypes of products in the real world.	Product Development and Processes
	Lack of optimization of processes also leads to the misuse of resources.	

Table 2- Sustainability Themes in the real world and their description (Compiled by Authors)

A graphic display of websites pondering on the above-mentioned themes is made in Figure 2.
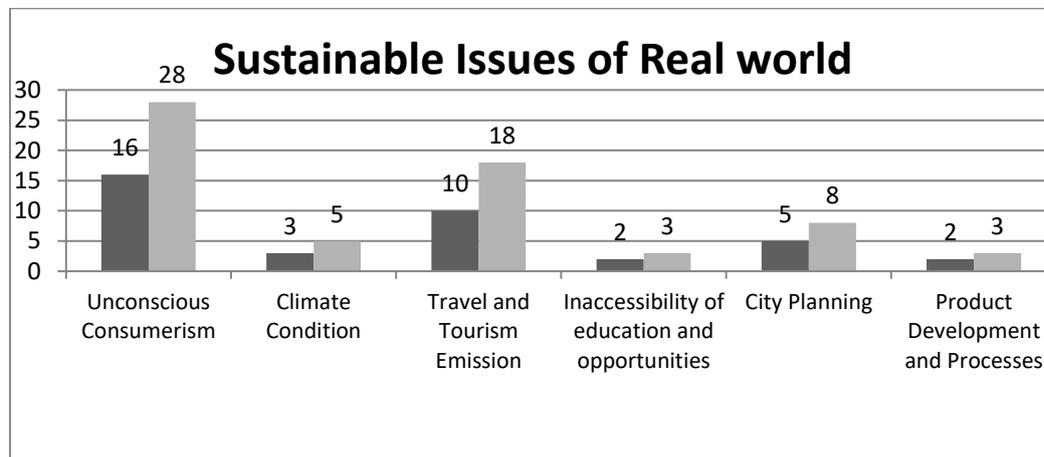

Sustainable Issues of Real world

Figure 3- Discourses with perspective on Sustainable themes in the real world (Compiled by authors)

5.0 Analysis and Discussion

"The future workspace liberates us. We gather the best of the two worlds - the touch and the feel of the real workspace and the access and reach of the virtual workspace - under the convenience and flexibility of switching between the two" (Yang, 2022). The metaverse opens the door to new possibilities and offers promises that the physical world cannot, but these possibilities bring their sustainability issues. It is evident from Figure 2 that energy consumption and carbon emissions have been considered the biggest sustainable issue (referenced in 39 discourses), but the problem is not without a solution. Decarbonizing data centers and creating green power grids around data centers will reduce carbon emissions. Moving the data to the hyper-scale, green cloud will also reduce emissions. Energy consumption in decentralized blockchain technology can be vastly reduced by changing the chain from "proof of work" to "proof of stake", as already done by Ethereum.

E-waste is another theme (included by ten websites) challenging the sustainability of the metaverse because of the increased use of VR gadgets that use rare metals and non-renewable resources. The lack of a circular economy and technological obsolescence also affect e-waste creation. Increased production of these gadgets will also vie for electronic chips, compromising the production of sustainable products in the real world. There are two solutions: the first is technological advancement in such a way that these gadgets shall not be required in the metaverse, and the second is creating a circular economy.

Metaverse will be built on a decentralized approach; this approach eliminates manual intervention and mediation, resulting in the reinforcement of traceability and reliability. Decentralization of power ensures governance at the highest level. Privacy, security, and trust (raised by 3 discourses), inclusion, and diversity (raised by 5 discourses) issues plaguing people's perception of the metaverse can be solved by the safe decentralization approach offered by blockchain.

There is a real danger that the metaverse may affect our physical and mental well-being (only 3 discourses highlighted this). Generation Z is already spending 7-8 hours in the digital world, causing addiction. The metaverse has formed real-life perils for social relations and mental health. If businesses in the metaverse want to succeed in becoming "sustainable," they shall address these issues in the initial stages of their creation.

The legislation will create a unique problem in the metaverse; the physical world is divided into many states with their own laws. If people are working, playing, entertaining, or traveling in the metaverse, they

will fall into which territory? Will the metaverse have its court and judicial system? Some thoughts need to be put in this direction as well.

Metaverse is not all black; many websites present a balanced view, stressing the negative and positive sides of the metaverse. Metaverse convening -for work or play - with the ability to collaborate, recreate, and share due to the actual presence of the brain, will contribute to more live presence while reducing carbon emissions in substantial amounts. Digital twin equipped with the convergence of IoT, AR/VR, AI, and satellite-generated data will reduce carbon emissions, increase productivity, space utilization, and operational and maintenance efficiency. This will substantially reduce the carbon emissions due to travelling, as quoted by 14 discourses.

Sixteen discourses (28%) mentioned unconscious consumerism and unnecessary collection of physical assets as a potential sustainability threat; if this wasteful excess in the real world can be replaced by owning digital assets in the metaverse, it will be more expedient than exhortations not to shop. Virtual consumption of digital assets with immersive experience will require few natural resources, leading to efficiency in resource use. Apart from this, we envisage a future where the design and prototyping of materials and products can be done by digital simulation and in a remote setting by leveraging advanced technology and digital connectivity (Singh et al., 2019).

It is believed (5% of discourses) that the most significant barrier is our behavior in addressing climate change; immersive experiences in the metaverse may appeal to our emotions with the issue and help drive meaningful action. 8% of discourses cited the benefits in city planning; cities are already setting out Metaverse technologies such as augmented and mixed reality, the internet of things (IoT), digital twins, and blockchain to help them with municipal tasks ranging from tourism to resource management.

From the above analysis, it is evident that the metaverse in its early stage is promising and can take the shape we will give; hence, it is the responsibility of all stakeholders to build sustainability at its forefront rather than grappling with it in the later stage (Rajguru & Brüggemann, 2024)

6.0 CONCLUSION AND SOCIETAL IMPLICATIONS
Authors have added to the ever-growing body of discussion on sustainability and the metaverse. Although a fully functional metaverse will take ten more years to develop, it is not too soon to start a discussion about the metaverse's sustainability. The Metaverse can significantly enhance outcomes and lessen the environmental messes we will have to clean up as things progress into the future if it is built with sustainability in mind from the beginning.

People worldwide are trying to create something new, different from reality; hence, they debate and escalate potential problems and their solutions. A conversation is making rounds about green software, green data centers, and green technology (Zhang et al., 2023; Green, 2022) because of the conceptualization of the metaverse (Singh & Singh, 2023).

This study has brought forth the perspective of experts on sustainable issues the metaverse is facing with present technology and advancement in technology that may reduce these problems to some extent, but this is in the future. However, the future seems promising.

The study also put forward the sustainable development problem of the physical world and how the metaverse can be used to bring those problems to a manageable level. However, there is skepticism and fear regarding the metaverse's ability to be an answer to the problem, as aptly said by Donne (2022), "that money spent on digital follies could be taking precious capital away from the supply chain, where most emissions exist, turning Metaverse events into echo chambers awash with the empty green talk."

As evolution progresses forward, so too does technology. However, we must recognize that this advancement is precariously balanced on the brink of sustainability. At present, we are making tremendous efforts to make this world sustainable. With pervading poverty, hunger, discrimination, pollution, and reduced water supply, will we be able to walk away from the real world and live in the

virtual world? Will it not cause our depleting resources to be applied elsewhere than real? Sustainability is a fight for life processes; will the Metaverse support its fight? Real people will occupy the virtual world with the same behavior and attitude; will it remain sustainable for long? What will happen if Generation Z grows up devoid of social interaction in the real world? There are more questions than answers.

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