Metaverse and Its Impact on Climate Change

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Abstract A novel idea called the metaverse combines various technologies to offer a lifelike experience in a virtual setting. To realize its full potential, the idea must still be refined. People's opinions of the phrase are conflicted. Whether the metaverse is a beneficial thing or whether it will harm our future has been heavily disputed. Many critics think it might cause more harm than good, while many regard it as the next logical step for humanity after the internet. The impact of the metaverse on the climate is just one of many worries. The enormous computer power needed to implement artificial intelligence (AI) techniques could increase carbon emissions. A metaverse may also decrease the need for physical travel, saving a significant amount of energy and resources and lowering fuel use and the emission of toxic gases. This article is a study of various technologies used to provide an immersive experience in the virtual world and their overall contribution to environmental climate change.

Keywords Metaverse · Multi-technologies · Virtual reality · Climate change · Carbon footprint

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1 Introduction

The metaverse is the next stage of interaction and is an ultramodern concept. Since Facebook changed its name to "Meta" in 2021, the term "metaverse" has gained some popularity, but in essence, it refers to the fusion of immersive digital technologies to provide a life-like experience in a digitally constructed world. Modern technologies like virtual reality (VR), augmented reality (AR), artificial intelligence (AI), blockchain, and cryptography will be used to simulate the physical world in the metaverse. Augmented reality (AR) is a more sustainable form of VR that adds digital elements to a real setting, rather than creating an entirely new environment from scratch. Although the first Metaverse has not yet been constructed, there are already several examples that may be used to illustrate the concept.

A brand-new class of social media platforms and Internet applications called Metaverse incorporates many cutting-edge technologies. It exhibits sociality, hyper spatiotemporally, and multi-technology traits [1]. The idea of the metaverse is still one that is still developing, and various individuals are adding to its significance in unique ways. Our climate emergency needs us to act like grownups; the metaverse encourages us to behave like children. Before the metaverse is fully optimized, there is still much work to be done. Companies are vying with one another to develop the operating system of the metaverse as well as metaverse platforms. There are numerous industries where the metaverse can show to be a benefit for giving long-lasting experiences with better resource management and service delivery. Whether the metaverse is a beneficial thing or whether it will have an adverse impact on our future has been heavily disputed. Many critics think it might cause more harm than good, while many regard it as the next logical step for humanity after the internet. The biggest and most dangerous global challenge currently facing humanity is climate change. Extreme weather events are increasing, global temperatures are rising, and many species are in danger of going extinct. The impact of the metaverse on the climate is just one of many worries. It is no secret that any virtual experience requires energy. Recently the demand for this resource has risen well beyond the amounts we've required prior. Data Quest reports that experts are concerned that the metaverse could cause a rise in greenhouse gas emissions because it uses a lot of energy to train AI modules [2].

The need for cloud gaming for VR may result in an increase in carbon emissions by 2030. Additionally, the need for high-resolution photographs will rise, necessitating yet more energy. We can only speculate as to how the Metaverse will attain net-zero emissions as long as it is still in the early stages of development. We currently have no way of knowing if the Metaverse will be a success and overcome its uncertain environmental prospects.

2 Related Work

The concept of the metaverse is quite new and very less explored. Although the term "Metaverse" was coined long back in 1992 in **Neal Stephenson's science-fiction novel "Snow Crash"**[3, 4], but this road is still very less travelled. It is quite fascinating for AI and VR researchers. Even though we are still only on the doorstep of a virtual universe, setting up the Metaverse could be both challenging and full of opportunity. H. Duan et. Al consider metaverse opportunistic for students and implemented a blockchain-driven university campus prototype. As per their considerations, the three-layer architecture of metaverse is proposed which is a combination of the physical world, virtual world, and their interaction [5]. S. Mystakidis also described various prospects of a metaverse in the field of education. The author identifies various challenges related to metaverse implementation including health issues, ethics, data privacy, etc., and highlighted various application domains [6]. A similar threat is the concept of surrogate nature in which the human being will be far away from real nature in the metaverse. M. C. Rillig et. Al recognized such risks including energy consumption and biased nature representation [7]. A. Plechatá et. Al experimented to influence the dietary habits and food choices of 122 volunteers and observed a moderate-large decline in dietary carbon footprint one week after the intervention. The authors concluded that a complex VR intervention focused on visualizing the future consequences of individual food choices can promote positive change in sustainable eating habits [8]. The study of the literature reveals that we can only speculate as to how the Metaverse will attain net-zero emissions as long as it is still in the early stages of development.

3 Metaverse Key Technologies

The Metaverse is built on the convergence of augmented reality (AR), virtual reality (VR), and Artificial intelligence (AI) technologies, which enable multimodal interactions with digital items, virtual environments, and people. As a result, the Metaverse is a web of networked immersive experiences and social in multiuser persistent platforms. It requires a collaboration of many technologies working together in a seamless manner that the user is unaware of due to the high level of abstraction. Depending upon the services provided in the metaverse, various other technologies including blockchain, cryptocurrency, 5G, IoT, etc. as shown in Fig. 1 are involved in making the project successful. A small-scale version of the Metaverse might already exist with blockchain technology and NFTs, or non-fungible tokens. Blockchain is a highly secure digital transaction system that makes it difficult for users to access or change information in the system. NFTs are tokens that represent anything with a unique identity, including avatars and gaming items. The Metaverse could use these technologies to create a more streamlined and secure augmented reality.

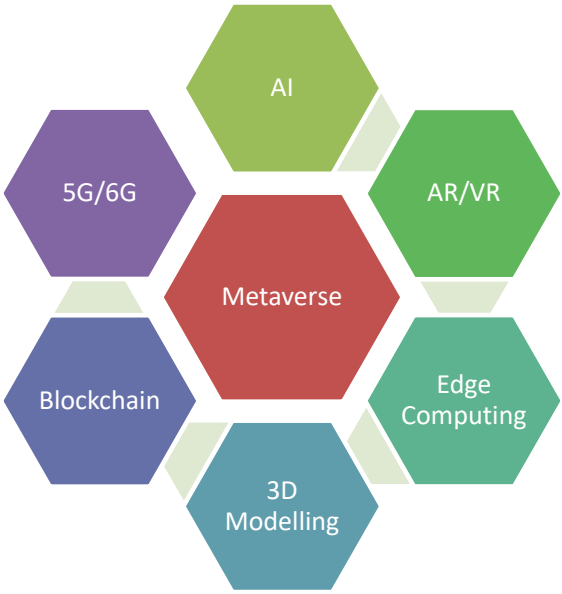

Fig. 1 Technologies Powering the Metaverse

4 Metaverse Challenges

Simultaneously, the dangers related to these ventures are challenging to survey as the desire to encounter reality may be more grounded than being taken part in virtuality [9]. These challenges offer tremendous opportunities ahead for consumers and companies alike [10].

a. *Identity*

One serious problem lies in proving your identity as bots can easily mimic your style, data, personality, and whole identity. You will need different verification methods like facial scans, retina scans, and voice recognition for authentication [11].

b. *Health-related issues*

Many research studies have explored the connections between children's use of electronic devices and mental health, and the results are clear: As use increases, so does the risk of mental health problems including depression, anxiety, ADHD, mood disorders, and suicidality. Teens who use electronic devices for more than two hours per day report significantly more mental health symptoms, increased psychological distress, and more suicidal ideation. Children using devices for more than 2 hours per day have an increased risk of depression, and that risk rises as screen time increases.

c. *Privacy and security*

A wide range of security breaches and privacy invasions may arise in the metaverse from the management of massive data streams, pervasive user profiling activities, and

unfair outcomes of AI algorithms, to the safety of physical infrastructures and human bodies. There have been incidents of emerging technologies, such as the hijacking of wearable devices or cloud storage, theft of virtual currencies, and the misconduct of AI to produce fake news, hackers can exploit system vulnerabilities and compromise devices as entry points to invade real-world equipment such as household appliances to threaten personal safety, and even threaten critical infrastructures [12].

d. *Legal aspects*

As with any groundbreaking technological development, the metaverse will raise novel and complex legal issues [13]. Possible legal implications of the metaverse are around data protection, marketplace transactions, virtual assault, etc. Questions about intellectual property are also highly relevant.

e. *Network and Infrastructure*

Major infrastructure investment by tech companies is needed to reach this market potential. Issues like low latency, network bandwidth, image resolution, cloud storage, consumer devices, etc. need to be dealt with for a seamless experience.

5 Impact on Climate Change

The Metaverse can revolutionize and provide users with amazing experiences because of its vast application domain. Tech professionals from all around the world have been working diligently and coming up with innovative solutions to rework the original Metaverse concept. The world can be altered by the metaverse. However, it is debatable whether or not these modifications will be sustainable. Numerous debates have been made on this topic. So, we have categorized the impacts of the metaverse into two classes: positive impacts and negative impacts. The detailed description is given below.

a. ***Positive Impacts***

This section describes the positive aspects of the metaverse. The metaverse has the potential to become a continuous extension of people's lives in a parallel virtual environment where they can choose to live, work, and play. The most straightforward environmental benefit of the Metaverse is that it allows physical events, constructions, activities, and products to take virtual forms.

- *Reduced physical travel*

It would be simpler for political and corporate giants to hold conferences online, saving them both time and astronomical costs for their security and travel. The main advantage for the environment is that it will require a lot less human travel, which will lessen congestion, mishaps, pollution, and ultimately global warming. The Metaverse has the potential to significantly reduce local and worldwide transport emissions if it is successful.

- *Equality*

In the metaverse, social boundaries are not entirely significant. The metaverse can also be referred to as the "World with no discrimination". The anticipated metaverse should be a more physical and direct society with diminished notions of race, gender, and even physical impairment, which would be extremely advantageous for civilization [5]. Equality enhances opportunities and makes the world a better place to live. The basis for everyone's ability to enjoy long, healthy, and fulfilled lives is equality. Promoting gender equality improves everyone's quality of life by eradicating prejudice, damaging stereotypes, and violence based on gender.

- *Improved health sector facilities*

Metaverse can take the health sector and surgical procedures to a whole new level. The metaverse will give new, cutting-edge approaches to maintaining our health. There is already virtual reality counseling accessible, and therapists are employing VR headsets to administer exposure treatment to patients so they can confront their fears in a secure, controlled setting. Additionally, some surgical procedures are guided by augmented reality technology where surgeons and digital twins can be used to practice surgeries.

- *Improved weather forecasting*

AI and Machine learning-based technology provide better weather forecasting tools to help scientists analyze and plan accordingly [14, 15]. Weather forecasts are a major benefit for society and sustainable development. To reduce weather-related losses and increase societal advantages, such as the protection of life and property, public health and safety, and support for economic development and quality of life, weather forecasting aims to give information that individuals and organizations may use. With the metaverse, weather prediction will become more immersive and help in government planning and policy-making.

b. ***Negative Impacts***

It's also not always obvious how and to what extent a particular growing technology may affect our environment, even though many people view expansion in the tech sector as a sign of societal advancement. However, despite the potential for good, the Metaverse may also have unfavorable effects on society and the climate.

- ***Increased Energy Requirement and Carbon Emission***

Because of the recent explosion in AI and the increasing availability of data and processing power, the demand for energy consumption is rising exponentially. Metaverse combines many technologies and for each service layer, the need for energy should be optimized. "According to a recent study, just one AI model's training may produce 626,000 pounds of carbon dioxide, more than five times the amount of greenhouse gases generated by a car throughout its lifespan [16]". Moreover, energy consumption by VR/AR headsets, networking devices, and other gadgets involved also contribute to greenhouse gas emissions.

Data centers and Clouds

A "superabundance of cloud-streamed data" is required by metaverse to present persistent better real-world like experiences in the virtual environment. Very high computing power is required for the generation of these data. This will lead to the rise in compute-intensive, fast and efficient blockchain transactions to govern metaverse commerce. As the metaverse is an amalgamation of many technologies like AI, Virtual Reality, and blockchain, all these technologies will demand more energy consumption and hence eventually affect carbon emissions. The amount of carbon emission will be largely determined by the efficiency of the data centers and power sources. According to a 2020 Greening The Beast study, "high-end gamers, which have the hardware required for state-of-the-art VR, will spend as much as $2,200 over five years on electricity and pump as much as 2,000 pounds of carbon emissions into the atmosphere each year." (Table 1).

The various elements of the metaverse will be heavily dependent on costlier servers. It is very difficult to determine the actual environmental impact levied by individual data centers. One study in this context claims that in 2015, data centers contributed to about 2% of total global greenhouse gas emissions which is approximately equal to the same amount as produced by the whole aviation industry. The researchers at the Lawrence Berkeley National Laboratory claimed that "the additional energy used in cloud gaming can cause annual electricity use to rise 40 to 60% for desktops, 120 to 300% for laptops, 30 to 200% for consoles, and 130 to 260% for streaming devices in 2016." In the current scenario of the increased domain of metaverse, we can expect an abrupt increase in energy consumption (Table 2).

Moreover, a study by researchers at the U.K.'s University of Bristol also claims that "30% of gamers using 720p or 1080p devices were to transition to cloud gaming by 2030, it'd cause a 29.9% increase in carbon emissions. If 90% of gamers moved to the cloud, it'd increase gaming's overall carbon emissions by 112%." (Fig. 2).

Table 1 Expected power consumption and carbon emission in high-end gamers in 2020

User	Estimated power consumption of 5 years	Estimated carbon emission per year
High-end gamers (having hardware for state-of-the-art VR)	$2,200	2,000 pounds

Table 2 Rise in electricity consumption by cloud gaming in 2016

Some components for cloud gaming	A rise in additional annual electricity use
Desktops	40 to 60%
Laptops	120 to 300%
Consoles	30 to 200%
Streaming devices	130 to 260%

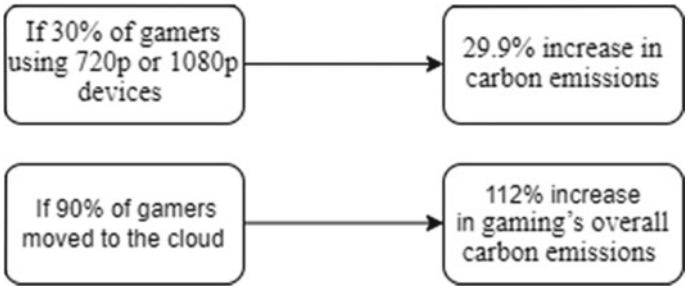

Fig. 2 Expected increase in carbon emission by cloud gaming in 2030

As metaverse engrosses the mass generation of decentralized data and this data needs to be stored in the cloud**.** Hence, more data centers are **required** to meet these growing needs, resulting in increased consumption of electricity. It also drives the shift of local data centers to the cloud. This shift may positively affect the environment.

Though the shift to cloud services emerged as a beneficial move but the energy requirements and consumption by data centers are also increasing. These days, IT cloud services account for about 2% of total global carbon emissions. The increased usage of digital services during the pandemic resulted in the release of 60 M tons emission of CO_2 in 2020 alone by Amazon. It could be foreseen that high-resolution imagery will require high data processing power in the metaverse. Moreover, as a massive number of users is brought into the universe from different platform providers, they will also significantly inflate these requirements.

According to Microsoft's lifecycle analysis, the Microsoft Cloud is about 22 to 93% more efficient than traditional local data centers in terms of energy consumption. To develop a sustainable and energy-efficient environment, cloud service providers are investing massive efforts in sustainable energy sources. Google claims that its data centers will be completely carbon-free by 2030 and Microsoft pledged to achieve this goal by 2025.

Though during the past decade, data center workloads from power consumption have been decoupled by their respective efficiency gains. From 2010 to 2020, data centers increased 9.4x and internet traffic 16.9x with only a 1.1x increase in power consumption. If cryptocurrency mining is not considered, only 1% of global electricity demand is contributed by data centers (Table 3).

Such efficiency gains are achieved with the use of hyper-scale data centers. These are specifically designed to restrain energy costs and invest in continual upgrades

Table 3 Affect of efficiency gains of data centers over power consumption

Year	Increase in internet traffic	The rise in data centers	Increase in power consumption
2010–2020	16.9x	9.4x	1.1x

and optimal sitting. The shift to Hyperscale represented a shift of 6% in 2015 to 45% of data center energy demand in 2021.

Some of the tech companies are meeting their electricity needs completely with renewable energy sources while others are also moving to "24x7 renewables", where the energy demand of each data center will be met by location-specific renewables at all times. These decarbonization achievements and impressive efficiency may be challenged by several other factors also. Data localization and privacy requirements may drive their companies to reinstate or keep their data centers. Moreover, for lifelike and compelling VR experiences low latency is demanded, which could shove data processing to the edge of networks, closer to users. Some data centers have to be in energy markets where acquiring renewables is not easy, or where operating conditions may affect the efficiencies or carbon-intensive back-up is required.

Training AI Models

As per Metaphysic's blog, "There will be markets for trading AI models to generate new content, much like users can purchase custom in-game items today. The combination of AI-generated content and virtual reality will allow for total immersion in alternative realities," But to train and run these types of generative AI systems, a lot of computation power is required. If we consider an example of OpenAI's DALL-E system, it comprises a text-writing AI system GPT-3, which is trained on pairs of text and images from the internet. 1,287 megawatts of energy is required for its training and consequently generates 552 metric tons of carbon dioxide emissions [17] (Table 4).

Some researchers at the University of Massachusetts said that 626,155 pounds of CO2 equivalent are emitted in training a single transformer AI model with 213M parameters [18]. As the platform providers try to provide enhanced user experience or provide relevant advertisements to each user, they continually invest in upgrading and developing the most accurate AI model. To build and test a final "paper-worthy model" approximately 4,789 models are trained over a six-month period, which releases more than 78,000 pounds of CO2 equivalent. This training process will be repeated continually for upgrading the commercial AI models in the metaverse and will significantly increase carbon emissions. It will be very dreadful for the environment.

Table 4 Power consumption and carbon emissions in training in different AI models

AI system	Carbon emission
Training GPT-3	552 metric tons of carbon dioxide emissions
Training a single transformer AI model with 213Â M parameters	626,155 pounds of CO2
In the training of 4,789 models over six months for building and testing a final â€œpaper-worthy model	78,000 pounds of CO2

Table 5 Carbon emission by single ethereum transaction

NFT	Carbon emission
One Ethereum Transaction	110 kg of CO2 equivalent to 42,734 VISA transactions or watching 18,253 h of Youtube

Environmental Impact of NFTs

In the metaverse, blockchain technologies will be of prime requirement. Blockchain offers non-fungible tokens (NFTs), which are unique for every audio, video, and photo of other media associated with them. NFTs come in form of digital creatures, music, artwork, avatars, and HTML code. It will also be in form of a plot of land in the virtual worlds. To enter and navigate among different worlds in the metaverse, the users can use authenticable and secure NFT avatars. As blockchain NFTs cannot be practically forged, they offer better security. Keeping track of ownership and trading of unique digital items, as offered by NFTs, will be an important component of the Metaverse.

According to a Digiconomist, "a single Ethereum transaction emits about 110 kg of CO2, equivalent to that of 42,734 VISA transactions or watching 18,253 hours of Youtube." When an NFT is transacted or minted, a new block is to be added to the blockchain, hence it would cost superfluously if creator studios are shifted to the Metaverse (Table 5).

Disposal of E-Waste

The risks posed by e-waste are real, and they are made worse by the unorganized sector, which frequently strips e-waste of its most beneficial components. Lethal substances like lead, cadmium, beryllium, mercury and brominated flame retardants are present in all electronic garbage. The likelihood of these hazardous compounds, contaminating the land, poisoning the air, and leaking into water bodies increases when gadgets and devices are disposed of illegally. The amount of worn and abandoned electronics is increasing along with the global demand for electronic devices. Every year, around 50 million tonnes of e-waste are produced, which more than the combined weight of all commercial aircraft is ever built. Instead with these things in mind, one can conclude that the Metaverse will be more detrimental to the environment than beneficial.

6 Conclusion

The metaverse, which will soon play a significant role in our lives, needs to be appropriate for users at all organizational and economic levels. This article describes various technologies involved in realizing the metaverse. The world can be altered

by the metaverse. However, it is debatable whether or not these modifications will be sustainable. Numerous debates have been made on this topic. So, we have categorized the impacts of the metaverse into two classes: positive impacts and negative impacts. Various positive and negative impacts of metaverse for climate change are analyzed. Additionally, by 2030, all of the IT behemoths, including Meta, Google, Microsoft, Apple, and others, will transition to zero-net-emissions and sustainable computing, utilizing more renewable energy sources. We can only speculate as to how the Metaverse will attain net-zero emissions as long as it is still in the early stages of development. We currently have no way of knowing if the Metaverse will be a success and overcome its uncertain environmental prospects.

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