

ITU Focus Group Technical Report

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ITU Focus Group on metaverse

Accessibility in a sustainable metaverse

Working Group 8: Sustainability, Accessibility & Inclusion



Technical Report ITU FGMV-16

Accessibility in a sustainable metaverse

Summary

This Technical Report ITU FGMV-16 promotes and instructs on the adaptation of an integrated approach to accessibility and sustainability in the metaverse. It explores the integration of accessibility products and services in the metaverse and their associated social benefit and environmental impact. Emphasizing the need for the early integration of accessibility and sustainability, this Technical Report presents information and guidance on how to incorporate sustainable accessibility products and services in the metaverse from the outset. Questions related to sustainability and accessibility in the metaverse need to consider the following:

- Social benefit of sustainable accessibility products and services in the metaverse;
- Challenges and opportunities of an accessible and sustainable metaverse.

Keywords

Accessibility, design, inclusive, metaverse, sustainability.

Note

This Technical Report is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1.0 of the ITU Technical Report on "*Accessibility in a sustainable metaverse*" approved at the 4th meeting of the ITU Focus Group on metaverse (FG-MV), held on 4-7 December 2023 in Geneva, Switzerland.

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Additional information and materials relating to this Technical Report can be found at: <https://www.itu.int/go/fgmv>. If you would like to provide any additional information, please contact Cristina Bueti at tsbfgmv@itu.int.

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Technical Report ITU FGMV-16

Accessibility in a sustainable metaverse

1 Scope

This Technical Report presents ways in which to integrate accessibility products and services in a sustainable and energy efficient metaverse for people with diverse access needs. It covers a range of guidance for making the metaverse sustainable and accessible.

NOTE – Specific guidance on the system design and user requirement for accessible products and services in the metaverse are provided under "Technical Specification ITU FGMV-04 – Requirements of accessible products and services in the metaverse: Part I – System design perspective" and "Technical Specification ITU FGMV-05 – Requirements of accessible products and services in the metaverse: Part II – User perspective.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 accessibility [b-ITU-T F.791]: The degree to which a product, device, service or environment (virtual or real) is available to as many people as possible.

3.1.2 artificial intelligence [b-ISO/IEC 2382]: An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning.

3.1.3 augmented reality [b-ITU-T J.301]: A type of mixed reality where graphical elements are integrated into the real world in order to enhance user experience and enrich information.

3.1.4 diverse users [b-ISO/IEC 71]: Individuals with differing abilities and characteristics or accessibility needs.

3.1.5 easy-to-understand language [b-ISO/IEC 23859]: Any language variety which enhances comprehensibility. Note 1 to entry: Easy-to-understand language includes plain language, easy language and any intermediate variety. These varieties share many recommendations, but the extent of comprehensibility is different as they address different user needs.

3.1.6 product [b-ISO/IEC 9241-11]: Item that is made or created by a person or machine.

3.1.7 service [b-ISO/IEC 9241-11]: Means of delivering value for the customer by facilitating results the customer wants to achieve.

3.1.8 virtual reality [b-ITU-T P.1320]: An environment that is fully generated by digital means. To qualify as virtual reality, the virtual environment should differ from the local environment.

3.2 Terms defined in this Technical Report

None.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

AD	Audio Description
AI	Artificial Intelligence
JPEG	Joint Photographic Experts Group
MT	Machine Translation
NMT	Neural Machine Translation
PNG	Portable Network Graphics
PoS	Proof of Stake
PoW	Proof of Work
PWD	Persons With Disabilities
SVG	Scalable Vector Graphics
SRT	SubRip
VR	Virtual Reality
VTT	WebVTT

5 Conventions

None.

6 Context

The metaverse holds the potential to revolutionize social interaction by providing new opportunities to communicate, learn, work, and interact online [b-Vlăduțescu]. However, as with any new technology, the metaverse presents various ethical, societal, and environmental questions that demand our attention. For example, how can we build a metaverse that is both sustainable and accessible to a diverse range of users and what form will it take? Questions concerning the future design and functionality of the metaverse have largely dealt with these two topics separately. This is despite the fact that both accessibility and sustainability are interlinked concepts that feature in the United Nations' sustainable development goals [b-UN SDG]. More specifically, goal 10 (reduced inequality) recognises the importance of ensuring the transition to carbon zero is inclusive to everyone, irrespective of age, sex, disability, ethnicity, religion, economic or social status. More broadly, the SDGs recognise the importance of developing sustainable solutions that safeguard against inequality and exclusion. Consequently, factoring in accessibility and sustainability in the metaverse requires a two-prong approach that considers the social benefit of accessibility services in the metaverse and their associated environmental cost.

6.1 Social benefit of accessibility products and services in a sustainable metaverse

In the age of accelerated climate change, ensuring that the metaverse is sustainable and easy to use for people of all capabilities is of pressing concern. Embedding accessibility into all sustainable initiatives in the metaverse safeguards against exclusion and improves its overall usability for a diverse range of users. For example, a less energy intensive metaverse can allow access for users with slower Internet connections or older devices. This in turn not only broadens the usage of the metaverse but also reduces the need for users to acquire new devices, thus curbing electronic waste. By addressing both environmental and accessibility concerns together, we can foster a more inclusive and sustainable metaverse that accommodates the needs and preferences of a broader spectrum of users.

6.2 Challenges and opportunities of an accessible and sustainable metaverse

As demand for energy increases, technological advancements such as the metaverse not only places an additional strain on the efforts to decarbonise the energy production in line with targets set out in the Paris climate agreement [b-UN Paris], but also present new and complex challenges in achieving these environmental objectives.

Accessibility services, such as interlingual subtitles and intralingual audio captions, are now an essential prerequisite to ensure that all users, including persons with disabilities (PWD), can exercise their human rights to equitable access to digital technology and content [b-UN CRPD]. Artificial intelligence (AI) can improve the accessibility of products and services by using underlying technologies such as speech recognition, text-to-speech, and language translation. When combined with blockchain, these services can be securely deployed and shared, making content and resources more accessible to users with disabilities and those who speak different languages [b-Oncins a]. AI technology such as machine translation (MT) has come to play an increasingly pivotal role in supporting the delivery of such accessibility services, specifically access to information in different languages [b-Greenwood 2017]. However, the computational power needed to train state-of-the-art neural language processing models comes at a significant environmental cost [b-Strubell], [b-Shterionov]. According to one case study, the carbon emissions associated with training the BERT language model were equivalent to a trans-American flight [b-Strubell]. The high energy demands of MT engines can be attributed to recent developments in hardware and training methods in the neural networks. While these recent advancements have improved accuracy, this has come at a considerable environmental cost [b-Strubell], [b-Shterionov]. Tied to these environmental issues are ethical concerns related to the use of the translator's data to train neural machine translation (NMT) engines [b-Moorkens] as well as data issues related to privacy, algorithmic bias, assessment, accountability, data ownership and security, and accessibility and inclusion. Despite the increasing computational power required to develop these NMT engines, such an increase yields only marginal gains in accuracy, especially for low resourced languages, i.e., languages that have limited availability of parallel text data, linguistic resources, and tools for training translation models for example, regional and minority languages like Catalan and Urdu [b-Shterionov]; [b-Goyle]. Against the backdrop of growing environmental concerns, redirecting our attention away from an exclusive emphasis on accuracy towards the development of energy efficient NMT engines can provide a path to simultaneously achieve environmental and accessibility objectives for the metaverse.

When considering the sustainability and accessibility of the metaverse, it is important to take into consideration the devices users will use to access it. To access the metaverse, users normally use a virtual reality (VR) headset, which poses several accessibility issues for users with additional access needs. For example, users with limited mobility might have difficulty performing the hand gestures required for metaverse navigation, such as swiping or pinching [b-Haynes]. Additionally, the weight, size and multimodal nature of the VR headset may pose problems for some users if worn over extended periods of time [b-Haynes]. Moreover, operating these devices may present difficulties for users who lack digital literacy skills, potentially exacerbating the digital divide.

From the perspective of sustainability, information and communication technology (ICT) devices such as smartphones, laptops, tablets, and VR headsets all generate waste throughout their lifespan. Up until recently, the pollution generated by ICT devices has been largely overlooked. One possible reason for this oversight is the fact that the manufacturing, production, and eventual disposal of the ICT devices including those that facilitate accessibility take place elsewhere, usually in developing countries where environmental legislation and labour laws are less stringent [b-Williams]. For example, most of the materials that go into ICT devices like smartphones and laptops – such as cobalt, copper, silver, gold, tin, tungsten, lithium, and tantalum – are extracted directly from mines in the developing world. This extraction comes at a significant cost to local communities and the surrounding natural environment. There is also the issue of the short lifespan of ICT devices, which poses a significant challenge to the efforts in reducing e-waste. Currently, the disposal of digital devices is outsourced to developing countries where a "backyard" industry has developed

[b-Williams]. A more energy efficient metaverse that can accommodate users with older devices, eliminates the need for users to upgrade or replace their devices. This not only lessens the economic burden on users but also contributes to the reduction of e-waste.

It is not enough to simply measure the environmental impact of the manufacturing and disposal of the ICT devices needed to support users in the metaverse, it is also crucial to take account of the operation of these devices. ICT tools and the digital infrastructure that supports them require energy. This energy normally takes the form of electricity. The source of this electricity varies from country to country. For example, the electricity used to power a device from a country that predominantly produces renewable energy like Norway emits less carbon into the atmosphere than a country like the United States of America (US), which derives most of its electricity from the burning of fossil fuels [b-Ritchie]. This energy is commonly referred to as "digital carbon footprint", denoting the subsequent unit of carbon emitted into the atmosphere as a result of digital devices and the networks that support them. This includes the production and operation of ICT devices and the systems that support them – from the cooling of the servers that store data to the electricity that is used to power the mobile devices. The complex supply chain and operation of ICT pose significant environmental risks that jeopardise our efforts to prevent lasting environmental damage.

If accessibility in the metaverse is to be sustainable, more attention to the environmental cost of the tools and networks that is used needs to be at the heart of all discussions about a metaverse for a diverse group of people. By embracing sustainability and accessibility as key cornerstones of a healthy society, we can build a metaverse that is truly sustainable and beneficial to diverse users.

7 General considerations

To fulfil the full potential of a metaverse, it needs to be built to be sustainable, accessible, inclusive, and equitable across the spectrum of ability. In line with the United Nations' SDGs, questions related to the sustainability and accessibility of the metaverse require an integrated approach that considers the social benefit and associated environmental cost of the necessary infrastructure to meet accessibility requirements. Designed well, the metaverse can lead to new opportunities for a wide variety of people to live, work and interact online by breaking down every day physical barriers, such as geographical distance and limited transport networks. However, if accessibility is not factored in from the development stage, the metaverse risks replicating wider societal inequity. Therefore, it is important to be aware of the impact of the choices that are made when a sustainable metaverse is designed so that it is open to a diverse range of users. This includes the adoption of accessibility and usability principles in all metaverse content.

8 Guidance on accessibility products and services in a sustainable metaverse

The following clauses provide guidance and questions to consider when designing a sustainable and accessible metaverse.

8.1 Ensure usability and accessibility by default

By adopting usability and accessibility conventions and best practices at the design stage [b-W3C], we can ensure that users with diverse access needs are met so that they can access, understand, navigate, and interact with multimedia content in the metaverse. This includes the integration of audio description (AD), interlingual subtitles and intralingual audio captions, to help users access, understand, navigate, and interact with multimedia content in the metaverse environment.

8.2 Avoid duplication of content

The duplication of content in the metaverse can lead to a higher energy consumption. By leveraging AI to generate content and accelerate the creation process, and utilizing blockchain to search for, identify, and detect existing content, we can reduce the redundancy of duplicated data. This not only

streamlines the creation and verification of content but also minimizes the amount of data needed to power the metaverse. However, it is important to weigh this against the substantial energy consumption associated with the use of some blockchain technology [b-Schinckus]. One strategy for addressing this concern is by prioritising the use of different blockchain consensus mechanisms, such as opting for proof-of-stake (PoS) over proof-of-work (PoW). In a PoS blockchain, the energy usage is considerably lower compared to PoW, as it does not rely on resource-intensive mining to authenticate a transaction. Instead, PoS designates validators to create blocks based on their ownership or "stake" in the blockchain network [b-Fernando]. With regards to accessibility, upcycling, or repurposing accessibility services such as audio description and subtitles, it minimises the duplication of content by identifying existing audio description and subtitling scripts that can be reused across different platforms or translated into different languages [b-Oncins b], [b-Jankowska] and [b-Orero].

8.3 Create simpler and cleaner user interface

A simpler user interface can be beneficial for a diverse range of users. For example, when a user interface is simple and well-structured, it ensures that users who rely on screen readers can accurately interpret onscreen information. Moreover, for individuals with low levels of literacy, a simplified design with clear and easy-to-understand language can help them access, understand, navigate, and interact with the metaverse content more effectively. It also lessens the cognitive load for some users, making it easier for them to focus on the task at hand. This is particularly important for ensuring equal access to information and opportunities.

8.4 Prioritise the use of icons for navigation

Prioritising the use of icons that are easy to read, in combination with alternative text, can enhance navigation within the metaverse. This, in turn, can lead to faster information retrieval and reduced search times within the metaverse, potentially contributing to the energy savings for user devices. Furthermore, prioritising the use of icons and alternative text in the metaverse can provide valuable assistance to users with low levels of literacy and those who use screen readers.

8.5 Build a more energy efficient metaverse for people and the environment

Building a more energy efficient metaverse is beneficial for the environment but also easier for users who use older devices or have slow internet connections. Efficiency can be measured by factors such as data consumption, accessibility across various devices, energy consumption, and the overall user experience. By optimizing these factors, the metaverse can save users money on data and extend the battery life of their devices. A more energy efficient metaverse can also save users money on data and extend the battery life of their devices. It also lessens the financial burden on individuals with older devices by eliminating the need for them to purchase new devices.

8.6 Find alternative file and media formats

Providing alternative file and media formats for informational and accessibility content can reduce the environmental impact of the metaverse and improve accessibility. Alternatives to video for informative content, such as scalable vector graphics (SVG) animation and real text descriptions can be more accessible and energy efficient compared with traditional video formats [b-Greenwood 2022]. Unlike Joint Photographic Experts Group (JPEG) and portable network graphics (PNG), which are composed of a grid of pixels, SVGs use mathematical formulas to define shapes, lines, curves, and colours, which means that these images are scalable. Since the graphics are defined mathematically, they can be scaled up or down to fit different screen sizes and resolutions without pixelation or blurriness.

With regard to accessibility in the metaverse, the choice of file formats may vary depending on the platform compatibility and specific requirements. For subtitles, the choice of a subtitle file format can also impact the overall file size. Larger file sizes require more energy to be handled, processed and

stored. The choice of a subtitle format often relies on the specific requirements of the platform, desired features (such as styling and positioning) and compatibility with the content being subtitled. Two commonly used subtitling formats are SubRip (SRT) and WebVTT (VTT). SRT files are generally smaller in size than VTT files, primarily due to their simpler format which includes basic text and timecodes for subtitles. VTT files, on the other hand, include additional features such as text styling and positioning, which can result in larger file sizes. However, the actual file size can vary depending on the content and the specific formatting used in the subtitle. Due to the immersive nature of the metaverse, information about the subtitle's placement will need to be incorporated into its design, which may result in a larger file size. Therefore for the sake of accessibility, VTT files may be a more suitable choice compared to SRT, as they are better tailored for an immersive environment such as the metaverse.

8.7 Use more energy efficient AI

Using more energy efficient AI can ensure a more sustainable and accessible metaverse by facilitating faster access to information. AI supports accessibility services like speech-to-text software and text-to-speech software as well as MT. Using a more energy efficient AI, also referred to as "Green AI" [b-Schwartz], can lead to better outcomes for users of the metaverse in terms of accessibility and energy efficiency.

8.8 Create intuitive design and provide easy-to-understand language alternatives

Employing easy-to-understand language and simple, intuitive design can make the metaverse more accessible, improving the user experience and reducing its overall digital carbon footprint. By adopting easy-to-understand principles in the design of the metaverse, we can make it easier to access, navigate, understand, and interact with a wide range of potential users.

Bibliography

- [b-ITU-T F.791] Recommendation ITU-T F.791 (2018), *Accessibility terms and definitions*
- [b-ITU-T J.301] Recommendation ITU-T J.301 (2014), *Requirements for augmented reality smart television systems.*
- [b-ITU-T P.1320] Recommendation ITU-T P.1320 (2022), *Quality of experience assessment of extended reality meetings.*
- [b-ISO/IEC 71] ISO/IEC 71:2014, *Guide for addressing accessibility in standards.*
<[>](https://www.iso.org/standard/57385.html#:~:text=ISO%2FIEC%20Guide%2071%3A2014%20provides%20guidance%20to%20standards%20developers,built%20environments)%20used%20by%20people.>></p><p>[b-ISO/IEC 2382] ISO/IEC 2382:2015, <i>Information technology – Vocabulary.</i>
<
- [b-ISO/IEC 23859] ISO/IEC 23859:2023, *Information technology – User interfaces – Requirements and recommendations on making written text easy to read and understand.* <[>](https://www.iso.org/standard/77178.html)>
- [b-ISO/IEC 9241-11] ISO/IEC 9241-11:2018(en), *Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts.*
<[>](https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en)>
- [b-Fernando] Fernando, Y., and Saravannan, R. (2021), *Blockchain Technology: Energy Efficiency and Ethical Compliance.* Journal of Governance and Integrity. Volume. 4 No.2.
<[>](https://journal.ump.edu.my/igi/article/view/5872)>
- [b-FGMV-04] Technical Specification ITU FGMV-04 (2023), *Requirements of accessible products and services in the metaverse: Part I – System design perspective.*
<[>](http://handle.itu.int/11.1002/pub/822e20cf-en)>
- [b-FGMV-05] Technical Specification ITU FGMV-05 (2023), *Requirements of accessible products and services in the metaverse: Part II – User perspective.*
<[>](http://handle.itu.int/11.1002/pub/822e20f7-en)>
- [b-Greenwood 2017] Greenwood, F., Howarth, C., Poole, D.E., Raymond, N.A., and Scarnecchia, D.P. (2017), *The Signal Code: A Human Rights Approach to Information During Crisis* in Harvard Humanitarian Initiative.
<[>](https://hhi.harvard.edu/publications/signal-code-human-rights-approach-information-during-crisis)>
- [b-Greenwood 2022] Greenwood, T. (2022) *Digital Design for the Planet and People.* Green Digital Accessibility conference.
<[>](https://www.green-scent.eu/wp-content/uploads/sites/7/2022/11/Booklet_-_Green-Digital-Accessibility-Conference-11.pdf)>
- [b-Goyle] Goyle, V., Krishnaswamy, P., Ravikumar, K.G., Chattopadhyay, U., and Goyle, K. (2023), *Neural Machine Translation for Low Resource Languages.* arXiv:2304.07869.
<[>](https://arxiv.org/abs/2304.07869)>
- [b-Haynes] Haynes, A., and Alsaab, H. (2022), *Will the Metaverse be Accessible? Inside Equal Access,* Kent State University.
<[>](https://www.kent.edu/equalaccess/news/will-metaverse-be-accessible#:~:text=The%20metaverse%20spaces%20need%20to,successfully%20developed%20in%20that%20world)>

- [b-Jankowska] Jankowska, A. (2015), *Translating audio description scripts – Translation as a new strategy of creating audio description*, Peter Lang.
<https://www.peterlang.com/document/1048599#:~:text=Summary_of%20a%20three%2Dstage%20study>
- [b-Moorkens] Moorkens, J., and O'Brien, S. (2017), *Assessing user interface needs of post-editors of machine translation*, Human Issues in Translation Technology, Routledge. pp. 109-130.
<https://www.researchgate.net/publication/312121765_Assessing_User_Interface_Needs_of_Post-Editors_of_Machine_Translation>
- [b-Oncins a] Oncins, E., Serrat-Roozen, I. and Andres, F. (forthcoming) *AI-based blockchain solutions in Learning, Education, and Training: Ethical challenges from a user-centric perspective*.
- [b-Oncins b] Oncins, E. (2021), *Upcycling audio descriptions: towards a more sustainable model*.
<https://webs.uab.cat/arsad/wp-content/uploads/sites/251/2021/01/arsad_book_of_abstracts_21012021_1.pdf>
- [b-Orero] Orero, P., Torner, A.F., and Oncins, E. (2023), *The visible subtitle: Blockchain technology towards right management and minting*. Open Research Europe.
<<https://open-research-europe.ec.europa.eu/articles/3-26>>
- [b-Ritchie] Ritchie, H., Rosado, P., and Roser, M. (2020), *CO₂ and Greenhouse Gas Emissions*. Our World in Data.
<<https://ourworldindata.org/co2-and-greenhouse-gas-emissions>>
- [b-Schinckus] Schinckus, C. (2020), *The good, the bad and the ugly: An Overview of the sustainability of blockchain technology*. Energy Research & Social Science, Volume 69.
<<https://www.sciencedirect.com/science/article/abs/pii/S2214629620301894>>
- [b-Schwartz] Schwartz, R., Dodge, J., Smith, N.A., and Etzioni, O. (2019), *Green AI*. Computers and Society.
<<https://arxiv.org/abs/1907.10597>>
- [b-Shterionov] Shterionov, D., and Vanmassenhove, E. (2021), *The Ecological Footprint of Neural Machine Translation Systems*, Towards Responsible Machine Translation: Ethical and Legal Considerations in Machine Translation. Springer, Volume 4. pp. 185-213.
<<https://research.tilburguniversity.edu/en/publications/the-ecological-footprint-of-neural-machine-translation-systems>>
- [b-Strubell] Strubell, E., Ganesh, A., and McCallum, A. (2019), *Energy and Policy Considerations for Deep Learning in NLP*. arXiv:1906.02243.
<<https://arxiv.org/abs/1906.02243>>
- [b-UN Paris] United Nations, *The Paris Agreement*, 2015.
<<https://www.un.org/en/climatechange/paris-agreement>>
- [b-UN CRPD] United Nations (2006), *Conventions on the Rights of Persons with Disabilities*.
<<https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd>>
- [b-UN SDG] United Nations (2015), *Sustainable Development Goals*.
<<https://sdgs.un.org/goals>>

- [b-Vlăduțescu] Vlăduțescu, S., and Stănescu, G.C. (2023), *Environmental Sustainability of Metaverse: Perspectives from Romanian Developers*. Sustainability, 15(15), 11704.
<<https://www.mdpi.com/2071-1050/15/15/11704>>
- [b-Williams] Williams, E. (2011), *Environmental effects of information and communications technologies*. Nature. 479(7373):354-358.
<<https://pubmed.ncbi.nlm.nih.gov/22094696/>>
- [b-W3C] World Wide Web Consortium (2021), *XR Accessibility User Requirements*. W3C Working Group Note.
<<https://www.w3.org/TR/xaur/>>
-