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Metaverse: a possible sustainability enabler in the transition from Industry 4.0 to 5.0.

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Abstract

Industry 4.0 has supported and changed the way companies operate over the last decade. Today, the increasing focus on sustainability in all its pillars is initiating a critical process and revision about the Fourth Industrial Revolution. A new scenario characterized by human-centricity, resilience and social sustainability, named Industry 5.0, is emerging.

In this transition process, new and old enabling technologies are appearing, among them the Metaverse. Although its actual functions are not yet fully investigated, from different perspective this tool could adequately support the definition of Industry 5.0 by creating a symbiotic ecosystem between companies, workers and consumers. Against this backdrop, the aim of this paper is to investigate, through a systematic literature review, the role of the Metaverse in the approach to sustainability in order to understand in which way this technology can be useful for the transition. The results may support policy makers, managers and practitioners in understanding the role of Metaverse in sustainability and in the new wave of Industrial Revolution. Limits and future research steps are also discussed.

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1. Introduction

Industry 4.0 and its innovative purpose is now a well-established passage both at the level of companies and policy makers [1] [2]. Its development and the scientific debate that has accompanied it since 2012 is now widely rooted and evolved [3]. Industry 4.0 is deeply internalized in various areas, from such as sustainability [4], human resources [5], and supply chain management [6]. Then, in recent years, sustainability has come to the forefront of the Industrial Revolution scenario, becoming a key piece that is difficult to separate [7]. After years of study and investigation into the link between Industry 4.0 and sustainability, a strategic role in this connection is given by the European Commission, which has sanctioned how "Industry 4.0 is not the right framework to achieve sustainability" [8] (p. 5).

Thus today we begin to talk about the Industry 5.0 scenario that, building on the established foundations of the previous framework, defines a new wave of technological innovation oriented toward sustainability and the centrality of humans in development processes [9]. This evolution of innovation from a sustainable development perspective has supported numerous studies on specific enabling technologies of Industry 4.0 and 5.0 and their contribution to the social, environmental and economic aspects of sustainability [10]. From the nine enabling technologies [11][12] enshrined in the Industry 4.0 framework numerous others are emerging. Among them, the Metaverse is bringing the attention of businesses, institutions, scholars and citizens/consumers closer together [13]. The term Metaverse was coined in 1992 by science fiction writer Neal Stephenson. Its most basic definition refers to "the concept of a fully immersive virtual world where people gather to socialize, play, and work". It can be considered as a simulated digital environment combining different technologies as augmented reality or virtual reality and social media principles to improve way of interaction from users able to imitate the real world [14]. So, Metaverse can be considered a worldwide solution that incorporates different technologies as Virtual Reality (VR), Augmented reality (AR), non-fungible token (NFT) [15], where humans can work, play, and communicate and physical, augmented, and virtual realities will converge [16]. The Metaverse topic is certainly new in the scenario of engineering, management and innovation studies in general, but in view of the transition to the new Industry 5.0 scenario, it could be a valuable support [17]. In this perspective, some authors have begun to focus on Metaverse and Sustainability [18]. In particular, Jauhiainen et al. [19] proposed a systematic literature review to analyse the Metaverse and its implications for sustainability and De Giovanni [20] also offers an interesting analysis by associating the Metaverse with sustainable development goals (SDGs). Both authors agree on the need to explore this connection and the possible implications in various fields and from different perspectives. So, although the Metaverse is a much-observed topic in recent years and the literature is rapidly developing in many areas, its association with sustainability still remains poorly investigated in several respects: i.e. application, opportunities, challenges and measurement [21]. Given the growing interest in the Metaverse and the simultaneous focus on the new Industry 5.0 scenario and above all on sustainability in all its pillars, the analysis and in-depth study of the dynamics between the two topics is of paramount importance. Thus, in this scenario, the present research work intends to focus attention on the Metaverse and its connection with sustainability, providing a contribution to the literature on the subject of state of the art analysis and possible evolutionary trajectories. In this regard, the research questions asked are:

RQ1. What are the main topics in which the Metaverse is associated with sustainability?

RQ2. Which pillar of sustainability is most associated with Metaverse?

RQ3. What is the contribution of the Metaverse to sustainability?

The research questions posed aim at defining an initial state of the art on the literature dealing with Metaverse and sustainability in order to understand aspects dealt with and reflected on the three pillars, as well as the real contribution of these instruments to sustainable development. Using a systematic literature review as methodology, the paper will illustrate the findings, discussions of the three research questions, concluding the analysis with implications and future research steps.

2. Material and Method

The paper approach is based on a systematic literature review.

A systematic review was the optimal methodology in relation to the research questions posed, to analyse the state of the literature and to understand how and in what way the Metaverse is integrated into strategies. According to different authors (i.e. [22] [23]) the Elsevier's Scopus databases has been selected for the research. This systematic

literature review was carried out from the 17th of April to the 3th of May 2023. According with [24], [25] a systematic review organized in four steps was implemented: a) collection of the papers, b) descriptive analysis, c) selection of categories and finally d) content evaluation of the selected papers. The first step was based on the extraction of keywords from the “Metavers*” and “Sustainability” databases. Only these two keywords were selected in order to have an initial analysis focused on the main topic. The search returned 43 papers. It was decided not to perform any further selection by filtering or skimming, and all papers were accepted and included in the sample. This approach will allow us to have a broad view and not restricted to a single topic or thematic area, so as to include different areas of study and/or application as well as to have a systemic view of the Metaverse tool in relation to sustainability. Therefore, all the papers were collected into a database that made it possible to highlight the main characteristics of the research (type of paper, editorial location of the research, year, origin of the authors) and the specific paper evaluation in relation to the topic analyzed and pillar of sustainability investigated.

3. Results

The results were articulated on two different levels. On the first level, the main characteristics of the papers were analyzed, while on the second level, the characteristics of the research papers were analyzed more from a content analysis perspective ([26]; [27]).

3.1 Main characteristics of the papers

The first level of analysis highlighted some characteristics of the papers analyzing the Metaverse and sustainability. As can be seen from the first two tables (Table 1 and Table 2), the papers are predominantly “Articles” that investigate the topic (often through case studies). Of these, 6 are literature reviews that offer (like the paper mentioned in the introduction) a reflection on the state of the art of the literature. The area of study of the topic starts from “computer science”, which is the natural location of the Metaverse, but a strong interdisciplinary and breadth of applications and interest is evident, ranging from the “social sciences” to “medicine” and “biology” and the “arts and humanities”. This allows us to appreciate the versatility of the Metaverse and the strong drive towards achieving sustainability that now pervades every field.

Table 1. Type of the paper.

Document type	n	%
Article	30	70%
Review	6	14%
Conference Paper	5	12%
Editorial	1	2%
Note	1	2%
Total	43	100%

Table 2. Subject area of the paper.

Subject area	n	%
Computer Science	26	22,4%
Social Sciences	20	17,2%
Engineering	15	12,9%
Business, Management and Accounting	12	10,3%
Energy	11	9,5%
Environmental Science	11	9,5%
Decision Sciences	5	4,3%

Psychology	4	3,4%
Arts and Humanities	3	2,6%
Medicine	3	2,6%
Biochemistry, Genetics and Molecular Biology	1	0,9%
Chemistry	1	0,9%
Materials Science	1	0,9%
Mathematics	1	0,9%
Physics and Astronomy	1	0,9%
Veterinary	1	0,9%
Total*	116	100%

* The total number of subject areas is greater than the number of papers because some of them fall into more than one category

Another interesting aspect is dictated by the evolution of studies over time. It can be seen (see Table 3) that the Metaverse is a recent phenomenon that began to be discussed and published in 2015, but the real focus emerges from 2022 to the present. In fact, in these years we can say that the evolution and application of Industry 4.0 is complete and we are moving towards the new paradigm of Industry 5.0 [28]. In this evolution, the Metaverse represents a useful tool for participation and integration between man and machine [29]. At the same time, Industry 5.0 puts the spotlight on sustainability as a paradigm of technological development and human centrality [30]. In this context, the literature accelerates the interest and study of these topics.

Table 3. Paper per years.

Year	n.	%
2015	1	2%
2016	1	2%
2019	1	2%
2021	2	5%
2022	21	49%
2023	17	40%
Total	43	100%

Finally, the editorial placement of the papers was analyzing. The first three journals that stand out again emphasize the multidisciplinary nature of the topics covered (Metaverse and Sustainability). Sustainability (10 papers, 23% of the sample), Interactive Learning Environments (2 papers, 5% of the sample), Technological Forecasting and Social Change (2 papers, 5% of the sample) are the journals in which the topic most recurs.

3.2 Papers content analysis in a sustainability lens

The second level of study is supported by the content analysis methodology in order to investigate the issue of sustainability in the Metaverse. To accomplish this, the papers were observed by researching: the specific topic under study, the sustainability pillar studied [31] and finally the sustainability contribution of the Metaverse (positive, negative, both or not available). First of all, Table 4 shows the topic analyzed in the papers. By reading the papers, it was possible to create clusters containing homogeneous research topics. The main relevant area of study that emerges is that of “digitalization and enabling technologies” (13 papers, 30% of the sample). The Metaverse is investigated as an evolution and continuation of the digital transformation and juxtaposed with sustainability, which is more and more inextricably linked to this process. 3 of these papers (23%) belong to the subject area of Engineering and analyses technical aspects of the Metaverse such as fundamentals, freight transport and the energy sector [32] [33] [34]. The second interested topic investigated relates to “marketing and consumer”, his behavior and reaction in the face of the

Metaverse. The interaction between man, machine and virtual reality calls for reflection on data, privacy and numerous ethical and social aspects that may be connected to the Metaverse and also to social sustainability. “education” is also a firm and widely observed point within the Metaverse. Here too, sustainability is very much linked to the social aspect (see discussion).

Table 4. Main topic of the paper.

Topic	n.	%
Digitalization and enabling technologies	13	30%
Marketing and consumer	8	19%
Education	7	16%
Transportation	4	9%
Life and Health	3	7%
Emission	2	5%
Infrastructure	2	5%
Tourism	2	5%
Business Model	1	2%
Climate	1	2%
Total	43	100%

Table 5 shows the most detailed analysis of sustainability in relation to the Metaverse. In the various papers analyzed, the specific sustainability pillar(s) observed were identified. As the results show in this first phase of the Metaverse and sustainability study, the focus seems to be oriented on social sustainability (28 papers, 53% of the sample).

Table 5. Sustainability pillars analyzed.

Sustainability pillars	n.	%
Social	28	53%
Environmental	22	42%
Economic	3	6%
Total	53*	100%

* the total number is higher at 43 papers as some papers highlight more than one pillar of sustainability

Regarding the Metaverse contribution to sustainability, not all authors are able to express themselves unequivocally. Table 6 shows the various impacts identified. Most authors seem to lean toward a positive contribution of the Metaverse to sustainability (29 papers, 67% of the sample). Some positive contributions are empirically validated by the authors and refer to specific areas/applications (e.g. packaging reduction, reduction of CO2 emissions from travel, improvement of workers' conditions). In other cases, we speak of "future expectation" [19].

Table 6. Impact of Metaverse on sustainability.

Type of impact	n.	%
Positive	28	65%
Not Available	10	23%
Both (positive and negative)	4	9%
Negative	1	2%
Total	43	100%

4. Discussion

4.1 What are the main topics in which the Metaverse is associated with sustainability?

As Table 4 shows, the main topics where the Metaverse is discussed in terms of sustainability are: “digitalization and enabling technologies”, “marketing and consumer” and “education”. The first topic focuses on the ongoing process of companies, institutions in different sectors in the transition to management supported by modern technologies. In this context, the Metaverse is often associated with other enablers in achieving sustainability such as Virtual Reality (VR), non-fungible token (NFT) or block chain [35] [36]. In relation to the first topic, some authors claim a contribution of the Metaverse, together with the other enabling technologies typical of Industry 4.0, on environmental sustainability. The topic is controversial because it is well known that some technologies have considerable energy requirements. However, Zang et al., [37] state how networked integration between technologies and the Metaverse offers the possibility of reducing energy consumption. Similarly, Sing et al. [34] affirm the possibility of energy use reduction support through the Metaverse, with the creation of virtual power plants, for example. Metaverse, together with technologies such as NFT, are also associated with social sustainability. For example, [36] present the case study of a historical silver mining enterprise of the Miao ethnic group, devising a digital strategy based on the application of the NFT digital twin to preserve and maintain silver technology and safeguard labor. The authors discuss the relationship between industrial production and traditional artisanal industries, emphasizing how the Metaverse can contribute to the inheritance and development of silver typical of the area studied and proposing innovative solutions to promote the prosperity of intangible cultural heritage assets.

The Metaverse and enabling technologies can also contribute to the improvement of working conditions with important repercussions on social, but also environmental sustainability. In this sense, Choi [38] emphasizes how the Metaverse as a tool for virtual work is also useful for the redefinition of Megacities and thus useful to institutions as a support for the environmental sustainability of large urban centers, supporting a migration to peripheral and rural areas and contributing to their revitalization and development. In summary, an attempt at a joint analysis between Metaverse and sustainability emerges from this first topic, even if it is not always empirically validated. Some authors report concrete examples of the application and positive effects of the Metaverse on sustainability [39], others merely speculate on future valuations of how and when the Metaverse can contribute to sustainable goals [40].

The second interesting topic is “marketing and consumer”. In management context, Metaverse seems to be a tool investigated precisely in the function of corporate marketing and in creating a new relationship with consumers [41]. In this sense, the debate in the literature is focusing on the possible issues and impacts from the perspective of sustainability, in particular social sustainability [42]. In this context, Lee and Kwon [43] analyze, for example, the consumer experience in the new reality of the Metaverse in terms of sustainability and safety. Indeed, the new consumers of the Metaverse are mostly young people who populate the web and are familiar with the new virtual dimension. In this sense, the Metaverse must delineate a socially and ethically sustainable space, both in the relations between consumer and company, between different consumers and in the presentation of new products [44]. Sustainability is also associated with the Metaverse in marketing in relation to packaging and new product design.

Indeed, consumers in the Metaverse are very aware of sustainable development. In this sense, managers can effectively use the Metaverse to appeal to consumers and support the development of products and packaging through sustainable processes that require fewer resources and time than traditional interview methods. Again Arpaci et al. [21] on the topic of social sustainability in the Metaverse state that it is crucial to focus on consumer personality traits. In particular, performance expectation, social influence, hedonic motivation, price-value, habit, agreeableness, neuroticism and openness have a significant impact on the social sustainability of the Metaverse, so companies introducing such technology must pay attention to these factors. The third interesting topic linking the Metaverse to sustainability is that of “education”. Education not strictly referring and limited to the school/university sphere, but also as support for the development of entrepreneurial knowledge [45]. In the Metaverse, learners can interact with friends and/or an instructor through avatars to experience the learning content, with a number of facilitations and interactions compared to previous asynchronous virtual learning content. This enhances learning by also triggering a fruitful two-way exchange between participants that is not only formative but also socio-cultural and also with positive effect on social and learning motivation [46]. Lee and Hwang [47] argue that the Metaverse can be a promoter of factors relevant to the education of sustainable development-oriented students/citizens/entrepreneurs such as critical thinking, communication, collaboration, and creativity. Thus, Metaverse and education push more toward achieving

social sustainability through interaction and cultural exchange and personal growth geared toward the new needs of society [47].

4.2. Which pillar of sustainability is most associated with Metaverse?

What was examined with the first research question has already underscored the relevant contribution of the Metaverse from the perspective of social sustainability. Indeed, as Table 5 shows, the literature seems to tie the Metaverse closely to this pillar of sustainability. Next, an interesting and potential contribution of this technology also emerges in the pillar of environmental sustainability. An interesting contribution is that of Allam et al. [48] who investigates the application of the Metaverse in cities and thus in terms of contributing to institutions in achieving social sustainability. His analysis reveals several positive contributions of the Metaverse in terms of quality of life and social interaction. Monaco and Sacchi [49] state, for example, how in the search for social sustainability, the Metaverse, digital innovation and immersive virtual practices can provide additional opportunities to explore and advance research into the desires, needs, expectations and satisfaction of customers, travelers and citizens, helping to provide services and products closer to their needs. Although these contributions are interesting and concrete, the challenges for effective implementation need to be considered [48]. While we can theorize a positive impact of the Metaverse in terms of social sustainability, it is crucial to consider the impediments and necessary changes, including cultural changes, to embrace such innovation [50]. Risks related, for example, to safety, to the ethics of using the Metaverse, or even some health-related issues connected to the use of this new reality that have yet to be investigated and known in depth [51]. In this regard, [19] states how responsibility must be the guiding principle for the construction of the Metaverse with a view to social sustainability. Anshari et al. [52] also reiterate the concept of accountability, stating that the responsible and ethical use of data collected in the Metaverse is a prerequisite for creating a culture of transparency and employee trust, as well as a commitment to social responsibility.

4.3. What is the contribution of the Metaverse to sustainability?

Finally, with the last research question we sought to initiate thinking in terms of the Metaverse's quantifiable impact on sustainability. As emerges from the analysis (see Table 6) and observations above, a positive contribution of this innovation to the achievement of sustainability goals in its pillars (social and economic more specifically) seems clear.

This is often a positive contribution, however, with which are associated challenges or necessary developments/precisions, as in the case of the above-mentioned responsibility, but also the need for those implementing the Metaverse to equip themselves with knowledge and skills for its proper use [53]. Interestingly, [52] strongly reiterates how the Metaverse could take on negative meanings and at odds with sustainability, particularly social sustainability, if a process of building such technology based on responsibility is not set up and initiated. This contribution is significant in our opinion as it represents an essential starting point for initiating a process of sustainable development based on new technologies. It is also important to point out that 23% of the sample analyzed do not make a judgment in terms of the Metaverse's concrete contribution to sustainability. These authors merely describe to what sphere this technology is or will be applicable, in terms of society, business, environment etc., but without stating a concrete contribution. This aspect is also linked to the fact that in concrete terms, today, the application of the Metaverse is often limited to leisure and entertainment activities and still not included in productive activities or with greater economic impact [54]. So some considerations are only hypothesized.

Figure 1 summarizes the main aspects that emerged from the analysis.

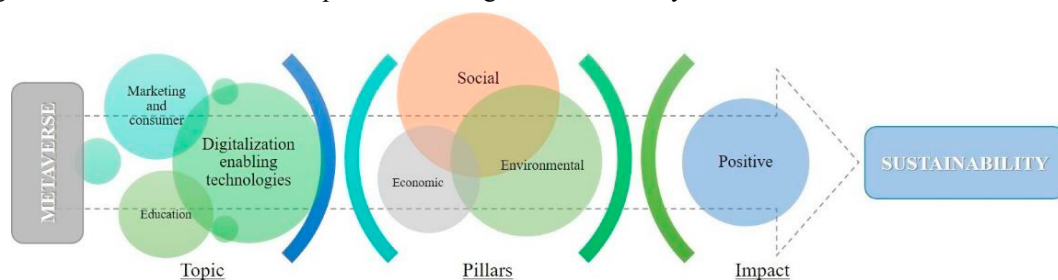


Fig. 1. Main aspects between Metaverse and sustainability

5. Conclusion

The analysis of the papers has allowed us to go into detail on the study of the Metaverse and its possible implications in terms of sustainability. To date, the study is still in an initial phase and the contributions often highlight a concrete but still not clearly definable link between Metaverse and sustainability. What emerges from the first research question seems to reflect a possible transversality of the Metaverse in different fields, with possible contributions to both social and environmental sustainability. This technology seems to be able to range from mere application in the field of computer science, up to management and medicine, with a marked interest in consumers, school education, transport, with a very pronounced social vocation. It seems clear that there is a positive impact in the use of the Metaverse in various pillars of sustainability (both social and/or environmental), but the aspect of the measurability of this contribution remains little investigated. In some cases, as emerged from the discussions, the contribution is controversial (both positive and negative), in others it is still not clearly decipherable. The paper offers hints for theoretical and practical implications. Indeed, the considerations that have emerged impose profound reflections that can guide the research, pushing it towards areas that have not yet been fully investigated. One of the most relevant gap emerged seems to be linked, for example, to the concrete measurement of the results of the Metaverse in terms of sustainability, but also challenges and opportunities need to be implemented and investigated in a more concrete manner, through case studies, experiments and empirical investigations. In terms of practical and managerial implications, the study allows policy makers, entrepreneurs and managers to evaluate the introduction and concrete application of the Metaverse at a macro and micro level, in decision-making and management processes, up to production processes, in order to orient even more the different contexts to sustainability. On the other hand, the considerations that emerged allow us to reflect on the challenges associated with the implementation of this technology. Even though we are in a transition phase from Industry 4.0 to Industry 5.0, there are still difficulties in adapting to these evolutions and the skills required for the correct implementation and use of technologies are an open challenge. Therefore, companies and institutions need to equip themselves with human capital trained and capable of dominating technology to create the foundation of Industry 5.0 "humans in the loop"[17]. In addition, training sessions for their users, consumers and/or citizens should be provided to facilitate their application and encourage their use [55]. Moreover, challenges remain in terms of ethics, privacy, data security as well as the need for laws and appropriate policy interventions to regulate and create a proper regulatory framework to enable proper and standardized implementation and use of the Metaverse. In this sense, the Metaverse requires extensive study and realization of the main opportunities and complexities. Therefore, future steps of research must be oriented towards a greater concrete connection between Metaverse and sustainability. For example, developing a set of measurement indicators adaptable to various contexts and useful for a concrete valorization of the impact of the Metaverse on sustainability represents, in our opinion, a necessary stage in the studies. At the same time, it is necessary to work on the skills necessary to implement and manage the complexities of the Metaverse. Ad hoc trained professionals will be needed not only on technology, but also on sustainable development practices. Consider, for example, the growing use of generative artificial intelligence, which could be a driver for the Metaverse by shifting the focus even more towards sustainability [56]. This requires a complex integration between different actors (companies, universities, research and institutions). However, it is necessary to pay attention to an important question: will the Metaverse actually have a future development? Indeed, many scholars are stating how the Metaverse could represent a meteor in the technological landscape and be already in a phase of decline (i.e. [57] [58]). Therefore, it will be ascertained whether this innovation can represent a real support for sustainable development and the new Industry 5.0 paradigm or whether it represents an element of fashion and transition towards more complex and advanced technologies.

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