D2.3: Report on Technological Foresight

Revision: v.1.0

Work package	WP 2
Task	Task 2.4
Due date	30/04/2025
Submission date	30/04/2025 (resubmitted on 22/08/2025, including list of participants as Annex) (Published online on 26/09/2025)
Deliverable lead	IF
Version	1.0
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Reviewers	TRUST-IT and INS
Abstract	This report builds upon different previous OV tasks, from WP 1, 2 and 3, to engage in and deploy a full foresight process, involving a diversity of experts and carried out mainly through a sequence of four workshops, from January to April 2025, to propose three scenarios of how virtual worlds could develop in the future, from a technological focus but also considering a variety of co-factors, for the 2030 and 2040 time horizons. The report aims to evaluate these three scenarios to eventually suggest a preferential track through key technological options and a series of open debates, with the objective of preparing the knowledge thresholding and policy issues of Task 2.5 on the road-mapping and policy recommendations for the virtual worlds and the Web4.0.
Keywords	Technology, virtual worlds, foresight, regulation, sustainable innovation

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	05/04/2025	Draft Outline of the Report and methodology	Pierre Rossel (IF), Gianluca Misuraca (IF)
V0.2	10/04/2025	Draft Report integrating previous work inputs	Pierre Rossel (IF), Gianluca Misuraca (IF)
V0.3	15/04/2025	Draft Report integrating workshops results	Pierre Rossel (IF), Gianluca Misuraca (IF)
V0.4	22/04/2025	Internal review 1	Silvana Muscella (Trust-IT)
V0.5	25/04/2025	Integrating comments from reviewer 1	Pierre Rossel (IF), Gianluca Misuraca (IF)
V0.6	28/04/2025	Internal review 2	Lukas Porwol (INS)
V0.7	29/042025	Integrating comments from reviewer 2	Pierre Rossel (IF), Gianluca Misuraca (IF)
V0.8	30/04/2025	Final review, editing and proof-reading	Gianluca Misuraca (IF) Pierre Rossel (IF)
V0.9	22/08/2025	Resubmitted, with list of attendees integrated	Gianluca Misuraca (IF) Pierre Rossel (IF)
V1.0	16/09/2025	Editorial review for publication online	Gianluca Misuraca (IF) Pierre Rossel (IF)

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Funded by the European Union

Project funded by
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Funded by the European Union (OPENVERSE, 101135701). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

This work has received funding from the Swiss State Secretariat for Education, Research & Innovation (SERI).

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Project funded by the European Commission in the Horizon Europe Programme		
Nature of the deliverable:	**R**	
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EXECUTIVE SUMMARY

This report presents a consolidated account of the foresight work carried out under Task 2.4 of the OPENVERSE project. It focuses on the evolving landscape of virtual worlds, their prospective impact on European society, and their challenges and opportunities for innovation-supportive governance. Grounded in a four-stage foresight process, spanning **expert elicitation, participatory workshops, policy benchmarking, and scenario construction**, the analysis synthesises inputs from interdisciplinary dialogues and strategic reflections to inform both policy-making and research agendas.

The findings underscore the critical need for anticipatory project-supportive and governance frameworks to address the complex interplay between technical innovation, societal values, and regulatory experimentation.

The first chapter examines key changes that have occurred globally and in Europe over the past three years, focusing on the innovative EU Commission proposal of July 2023 concerning virtual worlds and Web 4.0. This proposal endorsed two main objectives:

1. Building on initial OPENVERSE tasks to establish a foundation for forward-looking reflection.
2. Undertaking a structured sequence of four foresight workshops, involving a diverse group of experts, to develop contrastive scenarios for the 2030 and 2040 timeframes.

The second chapter synthesizes the outcomes of the foresight process, presenting three distinct scenarios for virtual worlds in 2030, complemented by reflections on potential developments by 2040. Details of the scenario-building methodology, along with the foresight rationale, summaries of each session, and new proposals for discussion, are compiled in Annex I of the Deliverable. This allows chapter 2 to focus entirely on the presentation of key insights and findings.

The workshops provided valuable knowledge to structure, analyse, and position the scenarios within the proposed topological foresight space, enabling the development of increasingly refined outcomes. However, this process also revealed several challenges, sparked discussions, and surfaced diverse perspectives from experts. These points have been compiled and organized in chapter 3 under the collective label of "open debates," with eight debates being examined.

Chapter 4 draws upon the most compelling ideas from the three scenarios to propose a preferred pathway for translating the foresight work into a practical roadmap. This roadmap is aligned with the next OPENVERSE task under WP2 (T2,5) and explores critical factors, including:

- Diverse co-creation tracks tailored to the various types of virtual worlds and their potential value for European development.
- The promising role of SMEs in driving open innovation, with opportunities for collaboration with leading European industry champions.
- The importance of skill development and the cross-disciplinary influence of virtual worlds on education.

- The significance of the user-designer-maker continuum across multiple economic sectors and interest groups.

- How "open" and "human-centric" principles can serve as foundational values, enabling European stakeholders in the virtual worlds ecosystem to harness their talents, align with economic priorities, and support community and sectoral aspirations through this rapidly evolving technology.

Virtual worlds are no longer speculative constructs or niche technological domains; they represent an emergent class of socio-technical systems integrating immersive technologies, increasingly decentralised architectures, and AI-driven interactivity. These systems are not simply extensions of existing digital infrastructures but signal a paradigmatic shift in how presence, creativity, agency, identity, and social interactions are conceived and experienced. The workshops conducted throughout the foresight process emphasised how stakeholders across academia, industry, and policy-making acknowledge the transformative potential of virtual worlds in sectors in the industry, education, health or cultural production. However, this openness also conveyed an important epistemic and strategic uncertainty regarding such dimensions pace, direction, and normative implications.

A central insight from the foresight sessions is that virtual worlds are at the confluence of multiple technological trajectories: **extended reality (XR), artificial intelligence, decentralised ledgers, and next-generation networks**. Their convergence gives rise to new socio-technical imaginaries, each with distinct assumptions about how the future should be stimulated and governed. The foresight work has thus moved beyond purely descriptive mapping of technological trends to explore the underlying values and tensions embedded within competing visions of virtual world futures. This includes tensions between openness and control, innovation and precaution, centralisation and decentralisation, market logic, and public interest. By embracing these diverse tensions, the foresight process aimed to anticipate future developments and shape them through reflexive deliberation.

One of the distinctive features of the process was its emphasis on cross-sectoral learning and mutual intelligibility between different stakeholder groups. In contrast to traditional expert-driven foresight, the **OPENVERSE foresight workshop series was designed as an inclusive space of co-creation, enabling participants to articulate divergent perspectives and surface latent assumptions**. This design choice proved essential in addressing the fragmentation of policy discourses on virtual worlds across different European contexts. It also allowed for a more granular understanding of how local cultural, institutional, and infrastructural conditions mediate the uptake and impact of immersive technologies. This insight aligns with broader trends in technology concerns, spanning from innovation programmes to intra- and extra-European governance endeavours, which increasingly foreground the importance of contextual sensitivity, pluralism, and responsible innovation.

The scenarios developed in the latter stages of the foresight process exemplify these pluralistic commitments. Rather than proposing a singular trajectory, the scenarios illustrate a spectrum of plausible futures, each shaped by different configurations of political will, regulatory regimes, technological maturation, and social response. They function as tools for strategic reflection rather than prediction, encouraging policymakers to interrogate assumptions, identify gaps and blind spots, and test the resilience of existing policy frameworks. Importantly, the scenarios also illuminate the socio-political stakes of virtual world development. Questions of access, equity, autonomy, and trust recur across the narratives, indicating that technical design choices will have far-reaching consequences for rights, agency, and social cohesion.

The comparative policy analysis further enriched this perspective by highlighting how different geopolitical blocs are positioning themselves in relation to virtual world development. The European Union's emphasis on values-based governance, fundamental rights, and digital sovereignty contrasts with the market-driven strategies of the United States and China's state-centred, techno-nationalist approaches. These divergences are not merely matters of regulatory emphasis but reflect deeper institutional and cultural logics. **For Europe, the challenge is to leverage its normative agenda into a competitive and innovative positioning without stifling innovativeness and experimentation or deferring too heavily to external technological agendas**. The foresight work suggests that this balancing act requires a multi-level governance strategy, capable of coordinating efforts across Member States while remaining responsive to emerging developments in standardisation, platform governance, technological innovation in key emerging domains, and AI regulation.

KEY CONCEPT #1: SOVEREIGN OPENNESS. The notion of **"sovereign openness"** emerges as a key concept in this context. It encapsulates the tension between Europe's ambition to remain open to global flows of knowledge, capital, and talent, while asserting control over the normative frameworks that shape technological development. This concept Was repeatedly invoked in the workshops as a way to articulate a proactive and principled stance vis-à-vis virtual worlds that embraces innovation while anchoring it in democratic values, transparency, and accountability**. Operationalising sovereign openness will entail difficult trade-offs, particularly around data governance, interoperability, and the regulation of virtual assets and identity systems, compatible with a demanding economic development strategy**. Still, it also offers a strategic narrative that could guide the EU's positioning in global debates and standard-setting fora.

KEY CONCEPT #2: CAPACITY-BUILDING & TESTING. The increasing need for **capacity-building and institutional experimentation** is a further finding of the foresight process. Current regulatory and research infrastructures are not fully equipped to contend with the complexity of virtual worlds, particularly in light of their transboundary nature and socio-technical fluidity. The foresight sessions identified a need for new institutional formats, such as **sandboxes, mission-oriented research programmes, and anticipatory regulatory mechanisms**, that can accommodate uncertainty while fostering inclusive innovation. These recommendations echo broader shifts in science and technology policy towards reflexive, participatory, and experimental approaches to governance.

KEY CONCEPT #3: FINANCIAL SUPPORT AND PARTNERSHIPS for SMEs. Additional **financing means and schemes, specific for innovative SMEs and start-ups** struggling in the Single Digital Market, are still much needed, especially considering the importance of collaborations with EU champions and their integration in dynamic public-private partnerships.

In conclusion, the foresight work conducted has laid the foundation for a more anticipatory, inclusive, and reflexive approach to both stimulating and governing virtual worlds in Europe. It demonstrated that technological trajectories are shaped by **political choices, social values, institutional arrangements and international competition** rather than being predetermined. Engaging diverse stakeholders in a structured yet open-ended dialogue has helped surface critical uncertainties, articulate normative orientations, and co-create plausible futures, and from the best ideas captured in the three scenarios, converging in what we called a meta-scenario, namely a transitional channel towards an effective policy-relevant roadmapping proposal. As a matter of fact, the challenge now is to **translate these insights into actionable strategies**, ensuring that Europe can both lead and shape the evolution of virtual worlds in ways that are democratic, inclusive, sustainable and yet economically engaging.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AI	Artificial intelligence
AR	Augmented Reality
BC	Blockchain
DMA	Digital Market Act
DSA	Digital Service Act
DSM	Digital Single Market
EU:	The European Union
IoT	Internet of Things
IPR	Intellectual property rights
LLM	Large Language Model
MS	Member States of the European Union
NGI	Next Generation Internet
VR	Virtual Reality
VW(s)	Virtual World(s)
XR	Extended Reality

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1 INTRODUCTION

1.1 OBJECTIVES AND SCOPE OF THIS DELIVERABLE

This deliverable D2.3, as a report, has the duty of presenting, explaining, and positively punctuating all the activities encompassed in OPENVERSE WP2/Task 2.4: *"Technological Foresight for an Open and Human Centric Virtual World"*. This mission implied:

- To produce a full-fledged foresight proposal dedicated to outlining the different factors and forces (enablers as well as barriers, among which technologies, but not only, meaning bearing an equal attention to European strengths and gaps), likely to shape the future of the virtual worlds and the Web4.0;
- Within that significant bandwidth objective and mainly from a technological focus as well as taking into account other essential co-factors and societal debates, to design and evaluate, practical and contrastive scenarios towards Open and Human-Centric Virtual Worlds, eventually proposing a preferential policy-relevant track for the years to come, for future roadmapping needs.

To carry out this complex duty, Task 2.4 has consisted of:

- Designing a complete methodological pathway, from initial inputs linked to the different first-year activities of the OPENVERSE project to the end goal of meeting the expected objective of Task 2.4.
- Identifying experts who could help us in that journey, including substantiating and enhancing our task leader's inputs towards that final goal.
- Establishing a consistent sequence of 4 workshops to make the collective foresight capacity assembled for that task tuned to the objective, namely configuring a virtual world model that can be open and human-centric, and at the same time promising for European developments, in socio-cultural as well as economic and political terms.
- Making sure that the process gradually integrates the inputs of the participating experts towards a robust foresight proposal, having examined an essential series of stakes and influential factors along the way.

This report will be disseminated within the Consortium to support other task deployments, ultimately 1) helping build Task 2.5 on the roadmap and policy recommendations (involving therefore, as end-users of this Deliverable, policy-makers at EU and MS levels), and 2) nurturing the Observatory development (T6.3) and other OPENVERSE ongoing or remaining tasks.

1.2 DEFINING TECHNOLOGY FORESIGHT

Technology foresight, as defined by United Nations Industrial Development Organisation, is a participative process, aimed at examining the longer-term future of science, technology, economy, and society with a view to identifying the emerging technologies and the areas of strategic research that are likely to produce the greatest economic and social benefits.[1]

[1] https://downloads.unido.org/ot/47/04/4704632/MIYAKE_TII_STF_RER_2005_XPUKR03016_1.pdf

More broadly**, Technological foresight** is a structured, systematic process aimed at anticipating and analysing future technological developments, their potential impacts, and the opportunities and risks they may create for society, industry, and policy. It goes beyond simple prediction by exploring multiple plausible futures, identifying emerging trends, critical uncertainties, and possible disruptions. Technological foresight helps decision-makers build strategic resilience, guide research and innovation agendas, and shape proactive policies that align technological progress with societal values and long-term goals. By integrating expert knowledge, stakeholder input, and scenario-building techniques, technological foresight acts as a bridge between today's decisions and tomorrow's challenges, fostering informed, forward-looking governance in an increasingly complex and dynamic world.

1.3 THE CONTEXT

The world changed significantly between November 2023, when the OPENVERSE project was conceived, submitted, and positively evaluated for a Grant, and the end of April 2025 (when this Deliverable is to handed in).

Firstly, we must acknowledge as a key change, the need for the EU, first reflected upon, then formally expressed and eventually published as an official reference, to define and implement a strong strategy in a specific sub-domain of the digital sphere, **the virtual worlds**, but not as a narrow focus, much the contrary as part of a more extensive industrial, economic, political and cultural programme. An interdisciplinary and multi-stakeholders' view prevailed in this evolution, aiming to generate the framework for attractive, immersive and engaging user experiences, the notion of user being rich and large, as we shall see. This strategic move had a founding momentum in July 2023, with the publication of a key document: "Communication: *An EU initiative on Web 4.0 and virtual worlds: a head start in the next technological transition"*[2]*,* aiming at ensuring an open, secure, trustworthy, fair and inclusive digital environment for EU citizens, businesses and public administrations, thanks to four key pillars:

- Empowering people and reinforcing skills.
- Business: supporting a European Web 4.0 industrial ecosystem.
- Government: supporting societal progress and virtual public services.
- Shaping global standards for open and interoperable virtual worlds and Web 4.0.

This stimulating agenda has been accompanying us since the beginning, and, accordingly, this led the OPENVERSE project to refocus on the series of analyses and assertions linked to the importance of virtual worlds and Web4.0, within the broader ecosystem of the Single Digital Market.

Secondly, while in 2022, when Mark Zuckerberg announced with great commercial and even messianic expressivity his company's considerable investment in the virtual worlds (which he had to revise downwards after that), the real significant digital investment that took place since then, worldwide, was in the AI domain, and in particular (but not only) in the development of Generative AI and large language models (LLM). Not only the massive investments that have been claimed since mid-2023 as

[2] European Commission (2023). *Commission Staff Working Document accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An EU initiative on web 4.0 and virtual worlds: a head start in the next technological transition. Strasbourg, the European Commission,* COM (11 July 2023) 442/final.
SWD_2023_250_1_EN_autre_document_travail_service_part1_v4_3K83mndXW2k2dqTlJBYappzvg_97341.pdf

well as the race between the giants of the digital in the US and in Asia on this technology completely occupied the stage, but the developments taking place in integrated AI[3] as well as in Gen AI increasingly permeated in the virtual worlds and to such a magnitude that it has been thoroughly examined and commented in the foresight sequence and as a result, will be dedicated a sub-chapter in this deliverable (section 3.2.6).

Thirdly, considering that the international scene has become quite conflicting, there are, for the EU, clear technological sovereignty challenges to be coped with.

This evolution, which also displayed diverse influences against the political values that the EU is promoting, with commercial and technological struggles of considerable intensity and complexity, was exacerbated by the stunning strategic changes in 2025 in the US administration. How this uncertain climate will finally influence the domain which Task 2.4 had the duty to examine, in foresight terms, is still somewhat difficult to establish. Even more than ever, in this context, we must prepare for different options without knowing what the future holds. Being capable of evaluating them against one another is crucial for the EU to engage in the most robust tracks.

1.4 THE STAKEHOLDERS

These contextual remarks emphasise, if necessary, the importance of defining the stakeholders of this Deliverable: namely the different targeted users, in order of importance. We see three main groups of stakeholders:

- The primary users of our document are without a doubt the **policy-makers at EU level, at MS level, as well as regional or city level**, who can nurture their strategic understanding and decision-making processes upon the proposal (the full-fledged package, intermediate debates, and, in all cases, the preferential scenario, meant to provide orientation and clues).
- The secondary users are **decision-makers and specialists** involved in the diverse technology-related developments of virtual worlds, as well as in their possible application in key fields of activity, technology being taken in the broad sense, i.e. including designers, media, educators, marketing specialists and investors concerned by emerging technologies and in particular with virtual worlds. These decision-makers and specialists may be active in all the key fields in which virtual worlds are expected to bring value and will be encouraged to develop in the EU, in particular in the domains of industry, security and defence, education, healthcare, smart cities, tourism, culture.
- Tertiary users may be envisaged in the **scientific arena**, as the foresight process we carried out has been structured, conducted and producing its results according to state of art practices in the foresight domain, and taking into account, as much as possible, the existing knowledge stock and expertise available to build our anticipatory perspective, therefore potentially useful for a diversity of scientists of both hard and human sciences.

[3] We refer with this notion to all the embedded services based on AI which involve no LLM nor open conversational options and which are based on specific application releases, capable of learning but managed by the owner/author of the service and its functionalities.

Of course, additional users of this deliverable may be envisaged, particularly end-users of virtual worlds, as well as EU citizens[4], the ultimate beneficiaries of the discussions we carried out and examined, considering the results that policy-makers and decision-makers of various types may put into practice.

1.5 COPING WITH A MULTI-FACETED TARGET

Beyond the evoked objectives lies the semantic stake of eliciting and positively exploiting the notion of "virtual worlds". This concept is not new, but it recently emerged as a solid reference, mainly, as mentioned in section 1.2, from a strategic reflection carried out by the EU regarding, on the one hand, the evolution of the digital (and in relation width the Next Generation Internet discussions[5]), on the other hand, related to the stakes and controversies associated with the "metaverse" notion, partly a source of confusion, with several competing terms overlapping such as metaverse, multiverse., omniverse, partly too, linked with the Zuckerberg announcement of September 2022 that it would represent, as such, the next Internet generation, a much disputed claim.

In this intense communicational process, the EU deployed a full-fledged proposal of its own implying that virtual worlds had to convey some specific characteristics to be qualified as such and eventually would have to be envisaged as a key track to the Web4.0, a stage of the digital in which complete interconnection of nearly everything and a positive blurring of the line between the physical and the virtual world would prevail; ideally, this would then open a broad bandwidth avenue to applications and creative solutions for all existing types of activities, while maintaining high the values behind the Digital Decade claim. These essential characteristics of virtual worlds have been coined as follows[6]:

> ***Virtual worlds*** *are persistent, immersive environments based on technologies including 3D and extended reality (XR). These technologies make it possible to blend physical and digital worlds in real time for a variety of purposes, such as designing, making simulations, collaborating, learning, socialising, carrying out transactions, or providing entertainment.*

[4] The targeted stakeholders and immediate relevant partners or beneficiaries of this Deliverable encompass a somehow narrower array of socio-economic actors than what has been looked for in the OPENVERSE Grant Agreement, as we expect the above-mentioned **stakeholders to be directly capable of making use of the content, insights and proposals of this document in their working environment**.

[5] There is an important convergence and even some overlap between the notions of Web4.0 and Next Generation Internet. The difference may lie in the respective scope and asserted assignments of each concept. While the Web4.0 stresses the interconnection among devices, data transferability, as well as the blurring between the physical and the virtual worlds, the Next Generation Internet (or NGI) embraces a large array of converging moves of communication technologies and infrastructures, but also concerning the governance and standardisation that it will take to make all the pieces work together with the expected level of performance and reliability, as well as criteria of security, privacy, inclusivity, equity, sustainability, decentralisation (instead of the domination of a few world players). NGI doesn't just focus on "what" the internet does (the tech), but also "how" it can serve humanity better (ethics, equity, and the environment). Let's also emphasise that the NGI concept positively intersects with the Strategic Research and Innovation Agenda (SRIA) objectives, which we will return to in the last chapter.

[6] The EU Commission (2023: 1): This semantic re-work is still not entirely achieved, on the one hand, because other players in the world do not necessarily follow that line of thinking, and on the other hand, because inside the EU-supported programmes, probably because it takes time to assume and fully implement a new paradigm, not all stakeholders have adjusted to it yet. We will leave aside here the possible definition disputes between the different reference concepts, we only observe the changes suggested, and support and work with them.

All definitions which have emerged between 2022 and 2023[7] encompass a series of standard features, despite nuances and possible divergences (which we will not dig into, leaving that to dedicated studies), where we can identify at least:

- **Immersivity** (a characteristic which is not bound to the sole virtual worlds) and which involves, in fact, several triggers, three important ones having been described in the Analytical framework of virtual worlds as expressed in the OPENVERSE Task 1.1, on which we will have to come back.
- **Persistency** (things that have been created or done stay accessible after the user turns the system off).
- **Synchronicity** (real-time operations).
- **3D** (although as we shall see, these characteristics may convey different types of conceptions and implementations).
- **The blurring of physical and virtual reality** (some authors even speak of these two dimensions as "merging", a debate in itself, and at least a foresight issue worth re-discussing)

To these essential co-properties, if we analyse carefully the definition proposed by the EU Communication of July 2023, and if we consider some of the purposes mentioned, in particular "*collaborating, socialising, carrying out transactions"* and to a lesser extent the other ones, we also have to consider the possibility of users, thanks to these four functionalities, of **engaging into social interactions**. As this feature is not indispensable, according to the definition mentioned earlier, we need to explain here why this was chosen as complementary to the first four to qualify existing virtual applications as virtual worlds, worth emphasising for our initial in-depth analysis of 75 such environments in OPENVERSE Task 1.1. To address the OPENVERSE objective of exploring co-creation with different kinds of users, designers and makers, the "social interaction" requirement was necessary to embrace the task with a maximum of options. However, let's acknowledge,, as OPENVERSE develops and as already explained in our Task 2.3 for the healthcare sector (Workshop of July 5th, 2024), it will also be able to re-envisage the XR options that do not entirely fit the social interaction criteria. This includes some high-end professional simulations and training applications in diverse domains, the development of infrastructural digital twins, in city management, for instance, which may not fully qualify on the social interaction criteria, but which may nevertheless contribute to shape virtual worlds in the years to come.

1.6 THE STRATEGY OF THE EU ON VIRTUAL WORLDS AND THE WEB4.0

The idea that virtual worlds represent the current transition of the World Wide Web towards a higher form of opportunity-giving and performance horizon, likely to touch all domains of activity, already conveys an implicit anticipatory tone. This is not yet our reality, as of today, but we can consider that claim as a stimulating announcement. The EU foundational document already presented goes into making this precision (op cit.: 4): *"(…) the Commission aims for a Web 4.0 that is powered by open and highly distributed technologies and standards that enable interoperability between platforms and networks and freedom of choice for users, and where sustainability, inclusion and accessibility are at the core of technological developments."* This broad set of expectations goes as far as fostering (op. cit.: 8): "A Virtual worlds toolbox for the general public", along with (op. cit.: 8-9): "Supporting a European Web 4.0 industrial ecosystem" and "Boosting the EU's technological capabilities". Strategically, these are extremely noble goals and quite normal expectations for a responsible political

[7] Among the proposers are the World Economic Forum, OECD, the EU Commission (as presented in this section), the European Parliament, and the US Congressional Research Center, to mention a few, yet important players involved in that exercise.

entity such as the EU. At the same time, if we keep our eyes on all the lines that precede, we have a series of objectives that do not match yet with present accomplishments and therefore talk about **a desirable future**. The Commission's document concedes that nuance, saying that:

"To ensure that Web 4.0, starting with virtual worlds, is shaped as an open, secure space, respectful of EU values and rules, international engagement is needed on a broad scope of topics, from technological issues (such as standards for interoperability, identity management or connectivity) to content and practice (such as content access and creation versus disinformation, censorship versus freedom of speech, and surveillance versus privacy)." (op. cit.: 14).

It is clear that we are, today (as of mid-2025), far from that, and even having to fight against movements on standards, identity management malpractice of all kinds, massive disinformation, and voluntary escape from effective content moderation on the part of major platforms. These are subject to huge fines from the EU, and they may hope to be part of the new Trump commercial deal and avoid either the fines or the denial of market access, should they overlook their duty[8]. Although enthusiastic about virtual worlds and the Web4.0, all the foundational documents of that period do not neglect the problems, hurdles, and contrary movements, balancing positive with more negative and risky features. The CERRE Report (Di Porto, Foa, and Ennis 2024) interprets this gap as the expression of an ineluctable maturation process, the current stage being the birth, then will come the infancy, and in the longer term, maturity. This looks like a foresight agenda where the various time horizons and substance would have already been defined, as they look mostly desirable, and nevertheless hopefully feasible and attainable with time and effort. Another way to formulate insights on the future is the one developed by the JRC (De Hont et al. 2023) in a very documented study, promoting and explicating the meaning of "Next generation of virtual worlds: why and why now", with different trend analysis and foresight-oriented supportive ideas (8 reasons of "why now type", legitimising the "Next Generation" assertion, which we will have to take into account and assess in our foresight process.

1.7 FORESIGHTING IN THE TECHNOSPHERE

The most basic principle to remember in foresight is that we do not know the future; it is far too complex and incommensurable[9]. The second principle is to be aware (and therefore engage in a corresponding reflexive activity) that we naturally tend to introduce our own biases in the process. The history of anticipation is full of stories of experts, from very famous actors to more ordinary ones, who missed key points. Where are the experts who predicted the Internet, the smartphone, the development of bullying in social media and the fast diversification of drones in actual warfare, just to take a few examples?

[8] Other supporting documents bring their own foreseeing contribution by proposing some bright future forecasts on the virtual worlds: e.g. EPRS (2022) on a Gartner announcement (Gartner 2022), and the spectacular formulation by Visionary Analytics and Idea Consult (2022), for the European Commission and on the basis of their study: "With an estimated global growth of €800 billion by 2030 and a potential 860,000 new jobs created by 2025, virtual worlds are set to transform the business and employment sectors in the EU". In this enthusiastic context, Accenture ventured into more ambitious forecasts, in which virtual worlds will be likely "to fuel a $1 trillion commerce opportunity by the end of 2025" (Market Screener 2023).

[9] We bypassed here the traditional discussion on technological determinism and solutionism. We acknowledge that these viewpoints exist and that they may occasionally appear in a foresight process involving a diversity of experts, but at the end of the day, we must make sure to be paying attention to the numerous choices and systemic co-factors expressed and likely to influence the apparently internal determination that technology may have for some very focused specialists.

Then, two questions arise: 1. What is the role of foresight if it is not to provide useful predictions? 2. What about forecasts and the status of forward-looking insights?

Answering the first question is easy: foresight is about envisaging several options, if possible contrastive enough to represent different choices to be made concerning the future, and evaluating them in the light of current interests constitutes a level of preparedness which cannot be replaced.

The second question is more difficult: we have no choice but to make forecasts, for a diversity of ordinary and less mundane objectives in personal life and society. We need them, but we also have to be evaluative of their underpinnings and level of reliability, a skill which is highly recommended and if not already part of both operational and strategic routines, to be developed. What can happen even in the most linear-looking future? The answer is: unintended diversifications, contradictory choices, and new problems of hampering impact (some technologies had to be abandoned, even after a great success). Technologies do not all develop at the same speed, nor as planned. There are "surprises" (the famous "wild cards" or "black swans"), which in the real-life (of innovation processes) may often mean: useful mistakes and serendipity, time-consuming trials and occasionally, the need for paradigmatic change, both in the science and the technology fields. Virtual worlds are not only technological objects or processes; they are technological configurations involving many human actions and choices in the loop, during their deployment, and in terms of investment, evaluation, regulation, and governance endeavours[10]. This is why, in our foresight journey, we will go step by step, each of them having to be defined, justified, and assembled into a broader knowledge pack, with all the possible methodological transparency.

1.8 BUILDING ON PREVIOUS OPENVERSE WORK

Prior to Task 2.4, the OPENVERSE project led to a series of interesting tasks and developments, some of which can be considered building blocks or at least insightful contributions to the targeted foresight process. This section presents the main OPENVERSE tasks of that kind.

Task1.1. ***Overview of existing virtual world environments*.** The task had the mission of providing a first sample list of virtual worlds which qualified under a strict compliance with the EU definition as presented in section 1.1 of this Deliverable, and thereupon, proposing an analysis of these virtual worlds, partly using an analytical framework of 10 dimensions and 29 sub-dimensions (systematically applied for a selection of 30 most promising virtual worlds), partly also involving other considerations such as the virtual worlds' geographical spread, the open source issue, the evolution of the platforms in time (declining or rising), the most popular platforms in terms of users, creators, virtual assets created or companies' turn over, etc., and, of course, the decisive factor of GDPR compliance. The final goal was to reach a short list of candidates for the OPENVERSE co-creation tasks (in particular T1.2 and T1.3), and the objective was attained, with a substantial gain in the knowledge of virtual worlds along the way.

This building, selection and analytical process, apart from understanding increasingly better a large quantity of virtual worlds and some of the key springs at stake (user empowerment, the distinct modes of existence of immersivity, virtual asset monetisation, cross-platform or multi-device offerings, the

[10] It is well known that there are several competing approaches and methodological claims in the foresight discipline. The approach chosen was not an ideal but a pragmatic design, matched by an assessment rationale and the scarcity of time.

sociology of these virtual worlds' constituencies, the increasing influence of blockchain and AI, etc.), constituted a significant start to engage in the many tasks and interactions planned within OPENVERSE.

Task 2.1. ***Technology watch and taxonomy, and T2.2, Marketplace of opportunities,*** were tasks led by Trust-IT and have much in common with Task 2.4. Still, as they were not entirely finalised when Taks2.4 took place, the foresight process had to start. It was only possible to build insights from direct interactions among task leaders. In particular, worth stressing is the notion of affordances, used by Trust-It to build its radar mapping, which seems quite promising, extending the effectiveness of virtual worlds beyond the notion of purposes which had until then worked with. This idea of affordances, which hints at the potential functionalities of why the users and creators of the virtual world arena would consider engaging in these environments (to summarise this notion), will come back in the further stages of how the foresight outcome of task 2.4 will nurture other OPENVERSE task, in particular the building of the Observatory. Similarly, the notion of "market" was examined by Task 1.1 for 75 virtual worlds, in terms of domains of activities in which virtual worlds were engaged (24 such domains scrutinised and used to identify mainstream trends deployed in the current virtual worlds).

Task 2.3. ***Identify the priority areas and the application areas*****.** Domains of applications, standardisation issues and IPR and SMES and start-ups active in the virtual worlds in the context of the Digital Single Market were the assignments of the three workshops undertaken within that task, which led to a considerable material, comprising workshop summaries and keynote presentations, which could be considered as preparatory steps for the foresight process, as well as some potential insights for other OPENVERSE tasks involving these topics (standards, IPR, ethics in particular). In the first workshop, the seminal relationship between XR developments and virtual worlds as envisaged by Task 1.1, especially in the healthcare sector, was examined, a topic which will come back to as a foresight stake. In the second one, we examined the centripetal and centrifugal forces shaping the standardisation processes envisaged as key factors for the virtual world future, in particular gaps regarding some 13 categories of standards (but in priority formats, security and interoperability, see for that section 3.2.2).

The last workshop had the mission of outlining how SMEs and start-ups could make use of the Digital Single Market, showing the importance of a broad-angle view on IPR[11], with the "openness" notion going much beyond the push of open source solutions.

Task 3.1. **Analysis of trends and benchmarking with the current Internet.** This task, led by IDC and INS, had the mission of identifying the current trends supporting the development of virtual worlds, and for that, a certain amount of literature was analysed, and a series of interviews with experts were carried out. The result, which can be accessed in a Deliverable (3.1), also involved several other OPENVERSE partners for specific chapters.

Worth stressing is the market and business orientation of the duty, which emphasised, among other criteria, the following concerns:

[11] In the OPENVERSE project, Task3.5 has the duty to fully propose a consistent track on this topic, and there is, as part of its assignment, the fully schematic inventory of the IPR options supported by the EU. For the EU recommendations, see in particular the GROW document (EU Commission 2022), which does not directly focus on virtual worlds, but treats all the main supporting technologies mentioned in this Deliverable (see section 3.2.1).

Market Adoption: This aspect explores the rate at which European businesses are adopting Virtual Worlds.

- Current Adoption: Analysing the prevalence of Virtual Worlds in European organisations across various industries, including government, education, healthcare, and business.
- Future Adoption Trends: Forecasting the growth of virtual world adoption based on factors like technological advancements, regulatory changes, and changing user preferences.
- Industry Perspective: Gathering insights from industry experts on the perceived benefits, challenges, and future outlook of Virtual Worlds in European organisations

Task 3.1 also considered some use cases to help predict the potential impact of Virtual Worlds on various industries and society as a whole.

- Short and Medium-Term Use Cases: Identifying the most promising and practical applications of Virtual Worlds in European organisations within the next few years.
- Foundational Technologies Maturity Assessment: Evaluating the maturity level of the necessary foundational technologies to support these use cases.
- Key Challenges: Identifying and addressing the potential challenges and risks of implementing Virtual Worlds in specific use cases, such as technical limitations, cost, and user acceptance.

Apart from other factors, such as ethics and openness, Task 3.1 quite naturally envisages, with some detail, the technologies which play a shaping role and are likely to continue to have that role in the years to come: AI, Blockchain, IoT, Clouds, 5G, Digital twins.

Concerning the adoption rate, the survey produced impressive results, revealing a growing interest in Virtual Worlds solutions among EU organisations: 71% of respondents either currently use or plan to adopt these technologies within the next two years. Let's quote the report (p. 23):

"Specifically, 23% of organisations are already utilising Virtual Worlds, demonstrating early adoption, while 38% plan to implement them shortly, indicating a positive outlook for market growth. Moreover, only 14% of organisations expressed no interest, highlighting the overall favourable perception towards these emerging spaces. These results suggest that Virtual Worlds are poised to become a significant part of the digital landscape in the EU, driving further advancements in technology and industry-specific applications."[12]

The report also provides statistics on the international growth of the virtual world market, expressed in "billions", but it is still a bit short of some of the forecasts mentioned earlier. Generally speaking, this study served as a first base for considering the market. The interviewees were identified as motivated and considered the future of virtual worlds in positive terms. Their opinion, if not strictly pertinent in pure terms of representativeness, expressed a strong threshold of interest to build upon,

[12] These percentages are interesting to relate to the JRC study already mentioned (De Hont et al. 2023), which had identified that some 27'000 activities are involved in the making of virtual worlds in one way or another, with 18'500 active entities in the EU perimeter. Let's mention, however, probably due to a different inventorying scheme, an official document of the EU (2025 a) which claims 8'500 active companies in the EU, while, in a further document, on the basis of the Visionary Analytics study of 2022, the same EU Commission (2025 b), forecasts 860,000 new jobs created by 2025. We are probably only in the beginning of having consistent and comparable figures for the virtual world arena. As Deliverable 3.1 identified eight major types of stakeholders involved in the making of virtual worlds, it would be interesting to cross-identify these categories with specific statistics, a further challenge to help support the economic actors who will make the most impact.

particularly in the professional usages of virtual worlds. Among the limitations mentioned: technical limitations, lack of specific skills, privacy and security concerns, integration of virtual solutions, unclear ROI, accessibility issues and lack of governance and standardisation, all factors on which the foresight study presented in this Deliverable will have to reflect.

Some trends which have a direct relevance with virtual worlds may have been omitted: 1. the growing ageing population, which is, to a large extent, for the lack of literacy or cultural fit with virtual worlds' mainstream, is excluded from the virtual world development as well as 2, the increasing concern which mental health represents (in general, but certainly not mitigated by the extensive involvement of the younger generations in videogaming and virtual world explorations, to say the least), and which increased during COVID. while it was precisely a golden age for virtual developments and headsets. Still, Deliverable 3.1 points out most of the trends we can rely upon to deploy our foresight process, which was one of its objectives.

1.9 TWO TIME HORIZONS

At the outset of the workshop sequence building, we first addressed the crucial question of appropriate time horizons. While multiple options were considered, two horizons were ultimately selected to frame our foresight process:

- **A closer timeline (2030)**, which aligns well with the road mapping requirements of Task 2.5, where actionable and short-to-medium term technological developments are necessary. This time frame is appropriate because it matches the typical planning cycle for technology roadmaps (5–10 years) and policy interventions[13], ensuring that the proposed actions remain relevant and actionable in the near future. Moreover, many trends in virtual worlds, such as AI-driven environments, mixed reality technologies, and regulatory frameworks, are expected to mature significantly by 2030[14].

- **A longer timeline (2040)**, which allows for the integration of more uncertain and emergent developments. Technological domains such as **neuro-connectivity**, **full brain-computer interfaces**, and the **systemic environmental impacts** of virtual worlds are characterized by longer innovation cycles and higher uncertainty. Historically, truly transformative technologies (e.g., the internet, smartphones) have needed 15–20 years from initial breakthroughs to attain wide adoption[15]. A 2040 horizon gives sufficient scope to anticipate slower-moving dynamics (e.g., standardization of decentralized platforms, societal impacts) and identify "wild card" developments that could exert pressure on nearer-term trajectories.

This dual time-frame approach also corresponds to best practices in foresight methodology, where one near-term "convergent" horizon and one far-term "divergent" horizon are used together to both inform immediate action and encourage long-term strategic resilience[16].

[13] https://commission.europa.eu/strategy-and-policy/strategic-foresight/2020-strategic-foresight-report_en

[14] https://www.weforum.org/stories/2023/01/defining-and-building-the-metaverse-davos-2023/

[15] https://www.gartner.com/en/articles/what-s-new-in-the-2022-gartner-hype-cycle-for-emerging-technologies

[16] https://www.emerald.com/insight/content/doi/10.1108/14636680810918586/full/html

Thus, choosing **2030 and 2040** balances the need for practical, immediate recommendations with the need to be alert to disruptive shifts that could otherwise blindside near-term planning.

1.10 METHODOLOGICA APPROACH

Task 2.4 involved the organisation of four workshops, which we structured as one consistent sequence with four successive sessions. We had to optimise these events, i.e. the time we would spend with the participants, the interactive tools used, and even the in-between phases leading us from one workshop to the next and then to the whole, as a scarce resource -time-, to exploit the available expertise at a maximum. Thus, although we varied the topics and the tools, we produced, systematically: 1. Topic indications regarding what the next coming workshop would hold (topics, goals regarding the scenario building process), and 2, after each workshop a double summary (one detailed acting as a report, the other one shorter, more executive and quickly read), notified to all participants[17].

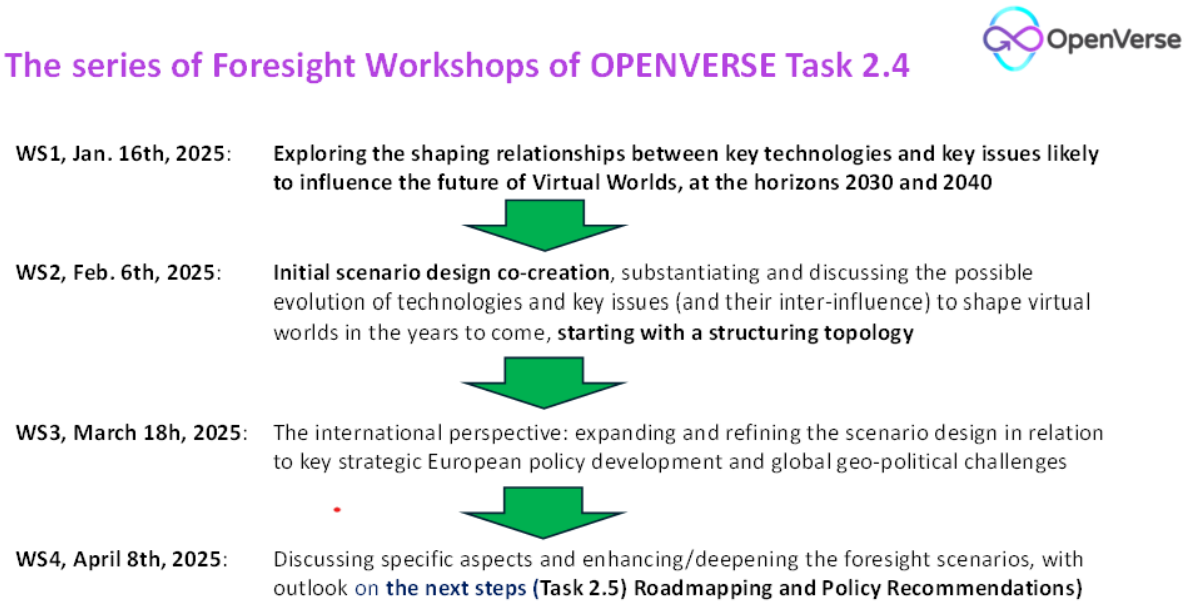

Fig 1. Overview of the four workshop sequence deployed in Task 2.4

[17] We also had to remind everyone, and each time (some participants were not involved in the four workshops), the objectives of the overarching task and the role of each session in the contrastive scenario building-and-assessment assignment.

2 A FULL-FLEDGED TECHNOLOGICAL FORESIGHT PROPOSAL

2.1 THE SCENARIO BUILDING PROCESS

The strategic objective of the OPENVERSE Task2.4 foresight process was not prediction but to construct a space in which to conceive, deploy and position plausible and contrasting futures, as useful policy-relevant insights. The scenario space which was designed to explore futures for virtual worlds and the Web 4.0 was not derived from abstract modelling but co-constructed through iterative, participatory engagements. To this end, technological, but also regulatory, geopolitical, economic, and socio-cultural factors were examined regarding their evolving interactions and mutual influence, and through the proposed co-creative process of the 4 workshops, they became active components in constructing a flexible, multidimensional foresight space.

The foresight process started by the confrontational examination of technological and non-technological factors. Among them, it is worth stressing the importance of two of them, quite different but equally influential for our topic: 1) the geopolitical arena as a competitive ecosystem producing its effects for all digital aspects, including virtual worlds, 2) the generational differentiation regarding virtual world practices and their role in each one's lifestyle

Geopolitical dynamics were treated as active conditions shaping the foresight landscape rather than as a passive context. Strategic autonomy was discussed as both a normative objective and a structural challenge. Comparative insights into alternative models, such as centralised state-led approaches in Asia or decentralised innovation clusters, significantly contrast with the EU–US binary often assumed in digital discourse. Participants debated whether Europe could define a distinct pathway without becoming a regulatory enclave or a dependent node in global infrastructures. Interoperability was highlighted as a technical goal and a strategic position, allowing Europe to shape the evolution of global standards and infrastructures through principled alignment. Emerging coalitions in the Global South, evolving US policy orientations, and assertive digital export strategies from China were all flagged as sources of increased volatility. These trends underscore the importance of strategic coordination and scenario testing, particularly in navigating uncertain geopolitical horizons.

The foresight process also recurrently tackled the generational issue, i.e. the way certain generations (classes of age which have been characterised as having, regarding the digital tools and practices, distinctive behavioural traits and references), and as such also paid considerable attention to the socio-cultural layer of the virtual world development. Issues of identity, memory, agency, and generational perception were central. A key theme was the emergence of "virtual natives", users for whom immersive interaction is habitual rather than novel. This generational shift brought forward debates on attention, emotional labour, and narrative coherence in immersive contexts. Some participants emphasised the potential for self-expression and participatory creativity, while others expressed concern over psychological risks and the erosion of shared reference points. The notion of synthetic memory[18], AI-curated or generated representations of personal and collective pasts, was exceptionally

[18] The term "memory" is used with different meanings in this document. Section 3.2.5 explains in more detail how younger generations (Gen Z and beyond) acquire information and communicate, and how this tends to permeate more and more

provocative. Discussions centred on its civic, ethical, and emotional implications, particularly in scenarios where such "memory environments" [19] become part of cultural and historical identity systems. While some saw value in speculative storytelling and pluralistic archives, others warned of authenticity, consent, and public trust risks.

Overall, these dimensions of the foresight process illuminated the human and affective stakes, as well as the societal layers of the virtual worlds' deployment and eventually, its governance. It suggested that technological and regulatory questions cannot be disentangled from more profound shifts in digital life's cultural values, generational norms, and emotional expectations.

Across four foresight workshops, participants collaboratively identified decisive factors, surfaced tensions, and mapped their interrelations, shaping a scenario architecture rooted in strategic uncertainty and experiential insight. This participatory approach rejected static trend extrapolation. Instead, it focused on constructing an anticipatory space defined by dynamic interactions between key variables. The resulting architecture was a scaffolding endeavour towards the creation of three distinct but interrelated scenarios. It captured the diversity of strategic possibilities without reducing them to predetermined paths, and placed equal emphasis on technological, governance, and socio-cultural dimensions.

The detailed process of this foresight exercise, designed to make the best of, and integrating the interactive production of a diversity of experts throughout four dedicated workshops, can be found in Annex I. Here is a fast track summary:

1. Examination of technologies that might influence the future of virtual worlds.
2. Examination of non-technological factors likely to influence the development of the supportive technologies of virtual worlds.
3. Definition of a foresight space to work with to co-construct contrastive scenarios, namely a topology defined by two axes understood as predominantly perpendicular. Defining proto-scenarios for the 2030 time horizon and tales of the future for the 2040 time horizon and beyond.
4. Examining and discussing these scenarios to propose a first topological positioning.
5. Discussing several issues likely to modify the initial topological positioning and let emerge important insights and tensions to enhance our scenario perception (evaluative mode), most of these issues were of immediate concern, but some more relevant for the 2040 time horizon

towards older generations, and become a culture of its own, almost a lifestyle. Bearing in mind our XR and virtual world focus, a first definition could go as follows: In the context of immersive civic technologies, "memory" transcends the traditional act of recollection, evolving into what scholars term "mnemonic ecologies", dynamic systems where memory is co-constructed through interactions between individuals, technologies, and cultural contexts. It encompasses creating, curating, and contesting shared narratives within digital environments. These virtual spaces serve as dynamic archives where collective experiences are preserved and actively shaped by community engagement. Immersive technologies, such as virtual reality (VR) and augmented reality (AR), facilitate the embodiment of historical events, allowing users to experience and interact with past occurrences in a multisensory manner.

[19] A memory environment denotes a **digitally mediated, often immersive ecosystem wherein individuals engage with past experiences, historical representations, and emotionally salient narratives**, either their own or those of communities and institutions. These environments are curated by integrating extended reality (XR), artificial intelligence, and participatory design, enabling users to revisit, reinterpret, or co-construct shared histories. Memory environments are not passive repositories but interactive and evolving spaces where memory is negotiated, contested, and emotionally experienced. See for that Bailey et al. (2012) and Kourtesis and MacPherson (2021).

6. Putting together and discussing the three contrastive scenarios developed up o the fourth workshop.
7. Designing from all the most stimulating features of the three scenarios, a meta-scenario likely to prefigure the further to come task to produce a policy-relevant roadmap (Task2.5).

2.2 A COMPREHENSIVE TECHNOLOGICAL FORESIGHT OF VIRTUAL WORLDS

As a reminder of the key hypotheses explained in section 1, let's stress that the "final" scenarios developed in this process and presented as a result of the four workshops sequence are best understood as co-created foresight constructs, not predictive models. They reflect a broad spectrum of expert inputs, participatory testing, and critical feedback. Their aim is not to determine what will happen, but to provide structured narratives against which to evaluate preparedness, resilience, and strategic policy alignment. Developed in a context of global uncertainty marked by rapid AI advances, shifting geopolitical alignments, and emerging governance challenges, they are intended to remain adaptive. Their robustness lies in their capacity to hold relevance under divergent conditions, enabling principled and flexible strategic reflection.

Fig. 2: A pictural overview of the scenarios co-constructed and discussed in the workshops

2.2.1 Scenario 1 – Developing our ambidexterity (The Architect's Dilemma)

By 2030, virtual worlds in Europe will have diversified into a **pluralistic and experimental ecosystem**, shaped by a combination of public policy, civic engagement, creative industries, and decentralised technological development. No single governance model dominates. Instead, actors across sectors and

Member States have embraced **adaptive, iterative experimentation**, navigating tensions between openness and accountability, co-creation and coherence. A new institutional logic has emerged: authorities facilitate sandboxed governance spaces rather than enforcing static rules, where regulatory frameworks are tested and adjusted in situ. These experimental zones span virtual learning spaces, cultural simulators, and collaborative design platforms. Citizens, developers, researchers, and policy actors co-shape governance principles through practice. Immersive experiences are no longer evaluated solely through performance metrics or safety standards, but also through their **symbolic, emotional, motivational and aesthetic dimensions**.

This is particularly evident in the realm of memory and heritage. Rather than aiming for objective reproduction, platforms and curators encourage **speculative storytelling** and **creative remixing** of personal and collective histories. Synthetic memory is acknowledged as a fiction. Still, it can serve, if properly regulated (e.g. with due transparency and accountability compliance), it can be exploited as a valuable civic and cultural function[20]. By 2030, a wide range of institutional models would coexist. In some Member States, public broadcasters have become trusted custodians of virtual heritage. In others, users' cooperatives manage digital commons, with governance mediated by smart contracts and ethical moderators. Interoperability is achieved not through technical standardisation alone, but through **cultural negotiation, mutual recognition, and collective evaluative capacities regarding the change that innovative digital applications and virtual worlds can stimulate.** Still, challenges persist. Multiple value systems and governance logics co-exist, producing **conflictual overlaps and grey zones**. Disinformation thrives in some corners of the ecosystem, as do speculative manipulations of narratives and collective memory. Institutions struggle to keep pace with the rapid cultural innovation emerging from decentralised design collectives and speculative AI artists. This is the dilemma: in a world of empowered digital agency and negotiated “virtualities”, **which draws the lines** between creativity and distortion, inclusion and appropriation, memorial loyalty and invention?

2.2.2 Scenario 2 – Values Will Make a Difference (The Price of Remaining Human)

By 2030, the European Union will have decisively asserted its values-based digital governance model within the expanding landscape of virtual worlds. Informed by the experiences of the late 2020s, marked by rising concerns over generative AI misuse, platform opacity, and immersive psychological effects, the EU introduced a comprehensive regulatory framework encompassing synthetic content labelling, emotional AI safeguards, and memory rights[21]. Each Member State implements national strategies aligned with this European framework. These policies establish rigorous ethical guidelines for immersive applications, particularly in healthcare, education, and heritage sectors. Public virtual environments, such as digital commons and institutional spaces, are regulated as critical infrastructure, subject to participatory oversight and transparency-by-design protocols. Innovation continues, but within **tightly defined ethical perimeters**.

[20] In fact, this problem is not so new. To understand the stakes of synthetic data and memory, see Sykes et al. (2008)

[21] Memory rights refer to the emerging normative claim that **individuals and communities should exercise agency over how virtual environments store, access, and govern digital memories, representations, and histories.** This encompasses preserving authentic historical records and mitigating synthetic or fabricated content that may distort collective memory or undermine identity integrity. In the context of immersive technologies, memory rights articulate the demand for traceable, transparent, and rights-based infrastructures that empower users to define the boundaries of their digital pasts and narratives. See for the research on that topic Chapman (2008) and Mandolessi (2023).

European actors lead the development of trust-enhancing technologies: verifiable content provenance, hybrid human–AI moderation systems, and virtual environments co-developed with civil society and minority groups. New institutions emerge to arbitrate the boundaries of digital identity, legacy simulation, and emotional immersion. By the 2030s, this governance model will have produced a **stable, rights-protective, and inclusive virtual ecosystem**, yet not without trade-offs. The strict regulatory regime slows the pace of commercial deployment. European virtual platforms struggle to scale globally, as developers tend to migrate and exploit their assets in jurisdictions with lighter regulatory burdens. An illicit parallel ecosystem of unregulated immersive services begins to flourish, offering unrestricted synthetic companions, nostalgia loops, and history rewriting packages. Despite enforcement efforts, some citizens enter these "shadow virtual environments" for unfiltered experience and affective gratification. Others remain committed to the European model, seeing it as a bulwark against digital coercion and ontological instability. A growing debate emerges over whether ethical guardrails protect or infantilise users, and whether the governance system is sufficiently adaptive to emerging threats, particularly from generative AI trained on dark data and counterfactual histories.

2.2.3 Scenario 3 – More of the Same Thing (Echoes of the Past)

By 2030, virtual worlds will become a seamless extension of daily life across Europe. The promise of persistent, immersive environments has been realised, mainly through the infrastructure and ecosystems operated by a small group of dominant global platforms. These companies offer frictionless access to AI-enhanced virtual companions, digital memorial archives, synthetic leisure spaces, and immersive education and work solutions. Customisation is deep, immediate, and emotionally tuned. AI systems would simulate familiarity with uncanny precision. Reconstructed voices and avatars of lost relatives could populate virtual memorial gardens. Memories are no longer stored but curated and re-experienced, guided by predictive algorithms that understand affective triggers. These features have become popular among an ageing population and diaspora communities. Yet they also spark controversy, blurring the line between remembrance and simulation, comfort and dependency. Regulatory oversight is limited.

While some Member States have adopted basic frameworks for transparency or data retention, most interventions remain fragmented or voluntary. EU-level governance prioritises interoperability, user safety, and market growth, hoping that soft coordination mechanisms will incentivise responsible behaviour. By the 2030s, concerns about the psychosocial effects of immersion intensify. Reports emerge linking prolonged exposure to AI-curated memory environments with emotional disorientation and deteriorating mental health. Despite this, adoption continues to grow. The convenience, aesthetic polish, and emotional fulfilment these worlds offer outweigh most users' concerns. Platforms increasingly shape the design of digital spaces and the architectures of social interaction, emotional validation, and even historical understanding. In practice, the line between archival preservation and speculative fabrication dissolves. While some civil society actors campaign for "memory rights" (an already defined concept), "synthetic content disclaimers", and "integrity and control over digital identity", these remain marginal. Efforts to create a European open-source, public-sector-based, interoperable alternative persist but struggle to achieve scale. Users gravitate towards the platforms that "understand them best", even if these platforms also own their past and, to a great extent, the data they manage.

2.3 A LOOK TOWARDS 2040: DEEP UNCERTAINTY AND EMERGING HORIZONS

Extending the foresight horizon to **2040** marks a deliberate shift from trend-based forecasting to strategic exploration under **deep uncertainty**. In contrast to near-term projections grounded in current trajectories, this long-range perspective recognises the **non-linearity**, **interdependence**, and **emergent complexity** that define technological and socio-political evolution over the next two decades.

Rather than seeking to predict the future, the 2040 horizon acts as a **cognitive sandbox**—a space to stress-test today's assumptions, policies, and infrastructures against potential long-term disruptions and transformation pathways. This approach aligns with **second-order foresight practices**[22], which favour reflexive, exploratory thinking over deterministic planning.

Why 2040?

The choice of **2040** is intentional. It lies just beyond the horizon of many institutional strategy documents, enabling both visionary and cautionary exploration. It's a timeline that intersects with the full societal uptake of exponential technologies[23] , the maturing of generations raised within immersive and synthetic environments, and the long tail of today's emerging regulatory and ethical frameworks.

While it provides no guarantees, the 2040 frame offers a **conceptual testing ground**—not just to map what might be technologically possible, but to probe what might become ethically, socially, and existentially **desirable** or **undesirable**.

Emerging Transformative Signals Identified in Workshops

During our participatory foresight workshops, several signals of possible systemic transformation emerged. These were not uniformly agreed upon as "likely" but were regarded as **strategically significant**—whether due to their potential magnitude, irreversibility, or unpredictability.

- **Quantum computing, neural interfaces, and multisensory simulation**
  These could redefine human-computer interaction, agency, and cognition. Brain-computer interfaces (BCIs) could allow direct neural immersion in virtual spaces, while quantum systems might upend encryption, simulation, and AI capabilities.

- **Energy constraints from immersive infrastructures and AI systems**
  The rising computational cost of generative AI and high-fidelity simulations may collide with environmental limits, geopolitical tensions over energy resources, and the societal backlash against high-carbon digital futures. This reframes the sustainability agenda as integral to virtual futures—not peripheral.

[22] https://unesdoc.unesco.org/ark:/48223/pf0000264644

[23] https://search.worldcat.org/title/57201348

- **Ontological drift in perceptions of reality and identity**
  As immersive environments grow in sophistication and persistence, the boundary between "real" and "virtual" becomes less fixed. This may lead to psychological, philosophical, and legal challenges concerning identity formation, memory, rights, and the human condition.
- **Rise of meta-social ecosystems with novel norms and governance**
  Beyond platforms, virtual worlds may become new civilizational layers—environments where emergent social contracts, moral norms, and even governance mechanisms evolve beyond the reach of nation-states. DAO-like structures and AI mediators could shift how legitimacy is constructed.
- **Black Swan possibilities**:
  - **Regulatory shocks**—unexpected global consensus on regulation (e.g., banning emotional AI, mandating digital memory deletion);
  - **Decentralised emergence**—massive user migration to non-corporate, distributed virtual systems beyond current control structures;
  - **Systemic breakdowns**—from widespread virtual addiction to neurological harm or AI-facilitated manipulation eroding societal trust.

Foresight Under Discontinuity: From Robustness to Resilience

These developments may **not align with current scenario logics**. Their disruptive potential calls for a foresight approach that values **resilience over precision**, and **adaptive intelligence** over static strategy. This means building strategies that can **absorb shocks**, **shift direction**, and **reconfigure purpose** when needed.

The 2040 horizon invites institutions and innovators to ask:

- *What unintended consequences could arise from our current ambitions?*
- *What ethical and social infrastructures must we build today to prepare for non-linear futures?*
- *Are we ready to lead or respond to paradigm shifts in cognition, governance, and collective identity?*

2040 as a Strategic Mirror

Rather than being treated as an endpoint or deterministic vision, **2040 serves as a mirror**—reflecting back the long-term consequences of **today's design choices**, omissions, and power asymmetries and the other way around, too, namely how the further in time signals may influence today's or closer to us decisions. It encourages us not only to consider what could happen but also to engage in **normative foresight**: what **should** happen, and what futures are worth striving for.

3 KEY DEBATES

While the foresight process was taking place and the workshop producing comments, many focused discussions took place, sometimes with clear divergences expressed by the experts, which, of course, we had no time nor need to close nor settle, and on the contrary, which could be value as a rich substance to continue to reflect on futures. This is how a series of open debates emerged, for which the interest, consistent with the foresight deontology, is not so much to shut down a dispute by all means but to make these contrastive views truly precious informative supports, as tensional pieces of knowledge whose worthiness is more in the learning they convey than in the decision they can trigger. Concerning the workshops, the keynote presentations, the interactive exercises, and the scenarios, these debates can be seen as deepening probes, or exploratory windows, making it possible to exploit all the substance that the foresight process actually conveyed.

3.1 TECHNOLOGY: WHAT DO WE MEAN BY THAT?

A lot of people have already tried to inventory the digital technologies and what is impressive is the way things are categorised, often showing a specific purpose or a graphical arrangement, sometimes linked to a dozen or twenty technologies, but also for more ambitious attempts, dozens of even a number of technologies that can overcome the hundred. In the world virtual segment, there are technologies which are specific and others which are supportive (e.g. communication protocols), infrastructural (e.g. computing power) or of cross-cutting use (e.g. cloud and edge). Within the OPENVERSE project, we had so far two main attempts of depicting the technological environments, the first one being linked to Task and Deliverable 3.1, which presented an interesting swirling combination of many technologies, regrouped in six categories:

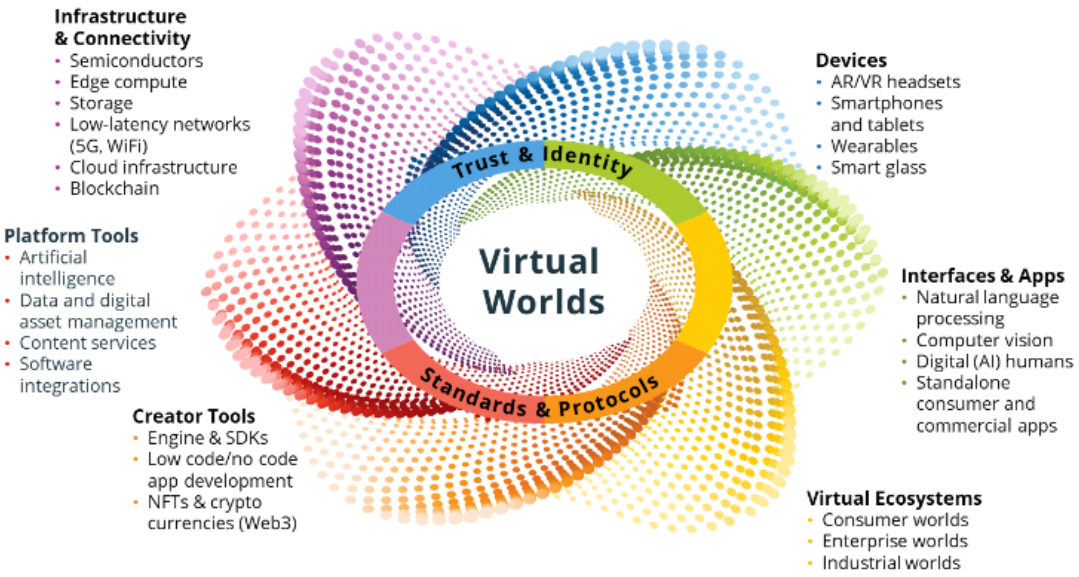

Fig.3. From Deliverable 3.1 and IDC Research: "Converging technologies around virtual worlds"

These categories are pertinent to virtual worlds. The graphical setting is nice but, of course, can be envisaged differently, especially when it comes to examining cross-linkages between some of

technologies. But we can consider it as a good starting point, even though a bit complicated to use for a foresight exercise.

The other Task in which there has been a systematic approach to the technologies involved in the virtual worlds so far (Task task2.1 and the Observatory, Task 6.3, both led by Trust IT, will still provide some other nuances, as well as Task 6.1 on Technological synergies), is task 5.3 "Collaborate and build synergies with other existing related EU initiatives" (Lead: BDVA). The authors of the corresponding deliverable produced successive views that are of direct interest to the technological foresight of virtual worlds.

The first one presents 13 building blocks, encompassing the whole technological landscape as we understand it, but without a clear internal structure.

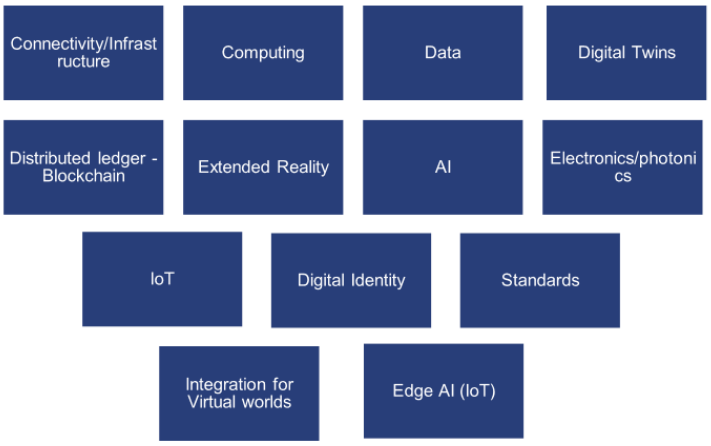

Fig 4: From Deliverable 5.3, Technology building blocks of virtual worlds (p. 13)

The authors attempted to link these building blocks to a virtual world ecosystem with concrete supporting projects, making an ideal, consistent whole. The relations between these different factors seem rather complex. The above-mentioned building blocks needed to be detailed with a more direct and concrete connection to the virtual worlds. With this perspective in mind, OPENVERSE tasks 5.1, 5.3 and 6.1 proposed a more comprehensive view of technologies for virtual worlds. They distinguished the key components of the following categories:

- **Infrastructure and core technologies:**
  - Hardware and devices: XR headsets (Meta, Varjo, Pico, PImax), holographic displays and controllers
  - Core technologies: cloud computing (AWS, Azure), GPU/HPC, 5G/6G, digital twins
  - Security and privacy: blockchain for authentication, OAuth authentication systems, anti-cheat mechanisms
- **Development and software integration:**
  - Programming and game engines (Unity, Unreal, C#, Udon)
  - Graphics and rendering (DirectX, OpenGL, Vulkan, shaders)
  - Networking and interoperability: Photon engine, OPENXR, SteamVR, WebRTC
  - AI and automation: Analytics, virtual assistants, OPENAI integration

- **User experience and content integration:**
  - User-generated content (UCG): Unity editor SDK, Blender, Maya, Autodesk 3ds Max,
  - Audio and multimedia: Opus Codec, Unity audio mixer
  - Digital identity and social graphs: Avatars, NFT-based assets, virtual economies

After having assembled in a compact representation all these components in one stack, the last step consisted in building a full-fledged detailed framework on technologies involved and key factors on which projects such as OPENVERSE have to work, attempting to some extent at the impossible, precisely representing the complexity of the linkages between all the factors and challenges at stake, and eventually proposing nothing less than a technological framework for the OPENVERSE project:

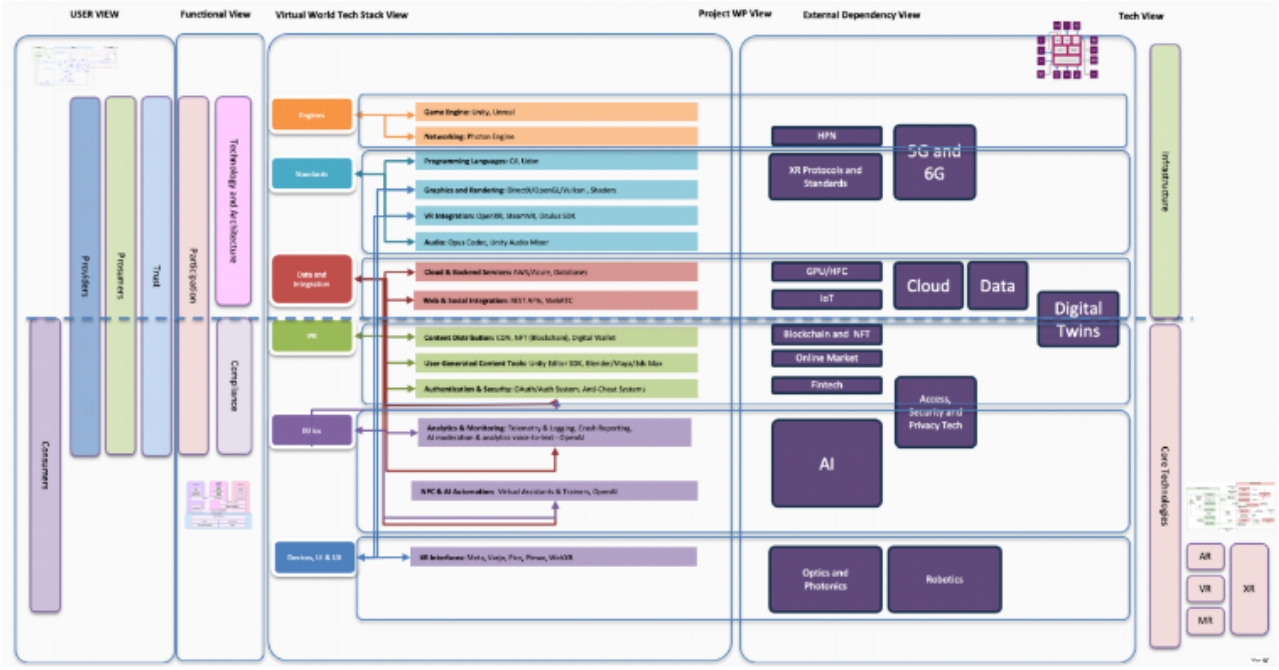

Fig. 5: From Deliverable 5.3, the Structure of the OPENVERSE Technological Framework (p. 29)

The attempt is valuable and in itself can be the trigger of new research and debates. As this activity developed somehow in parallel to the design of Task2.4 Foresight process[24], it has been impossible to advance in our duty without proposing a canvas of our own, regarding what we meant by technologies in the context of the technological foresight of virtual worlds and the Web4.0. This is why, quite early, we adopted a pragmatic categorisation, meant to enable all participants in the four workshop sequences to grasp the whole landscape quickly, with the different elements it encompassed, and the opinions they could express regarding their evolution. In any case, as for the models proposed by Deliverable 5.3, the first one would be too indistinct (we will see that we proposed a more precise categorisation, pragmatic and practical for our purpose), the second one, valuable in terms of project management, but not bringing more insights on technological roles/specificities, and the third one,

[24] The only proposition we had when starting our own assignment was the Deliverable 3.1 model, interesting, as we already said, but a bit too complicated for our own duty.

most probably a candidate for further analyses and internal fine-tuning (especially regarding synergies and helping with the radar view of the Observatory), but far too complex to use for the foresight process, and as we said, not yet available when we started our foresight design process. In reality, part of the foresight process was not to get too quickly to specific linkages that could relate technologies and challenges, but on the contrary, let the expert focus on the potential dynamics (the famous "field of possibilities" of foresight exercises), to create several options to lead to different scenarios, from which to choose thereafter.

We can understand that although others, in different OPENVERSE tasks, were busy reflecting on the technologies involved in the virtual worlds, the purposes that differentiated us also pushed us to envisage distinct modelling and categorisation approaches. Let's also observe that no satisfying solution has explained how the relevant technologies could be additive or even conjunctive to create new potential functionalities and services. In this context, we proposed the following, as seen here from the provisional sketch we designed for the first two questions of the foresight process (Workshop 1):

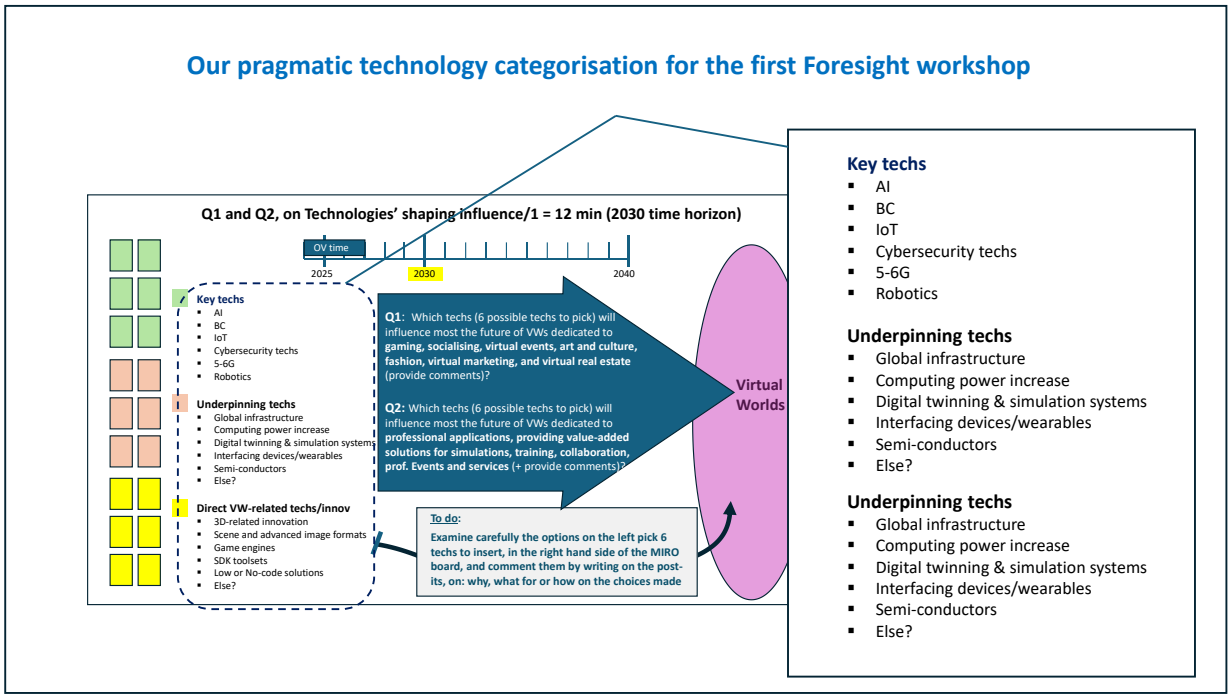

Fig. 6: Overview of our pragmatic technology inventory and categorisation for the first workshop

We can observe that we had to choose from an extensive array of technologies to develop something that experts involved in the foresight process could easily manipulate and comment on. This meant working with 18 technologies (within which one "else", for surprise propositions), assembled into three distinct groups, from top to bottom:

1. Which involve technologies which are helpful across the whole digital field but, as such, are also likely to shape the future of virtual worlds, and bear a particular importance in the current developments of the digital sphere;
2. Which involve technologies which have a generic influence on the digital at large, but are also instrumental for all the XR and virtual world arena;
3. Which are more specific to the development of virtual worlds?

Like all the ones we examined before, this distribution is highly disputable. Still, we had to find a compromise between details and precision/associated explanations and an easy-to-work-with categorisation. Finding a good relation between these requirements is a research topic in itself, but as time was so scarce (4 times 2 hours and between, light exchanges, to avoid saturating rather busy experts), we gave birth to this pragmatic list. We are aware, however, that it does not close the debate, nor represents the perfect set of technologies to consider for this exercise. We are happy to have been able to act swiftly and not get lost in debates and complex discussions. This pragmatic choice allowed us to ask clear, fast-track questions and get good and effective comments.

3.2 STANDARDS

As we saw in the first section, one of the Commission's main requirements linked to the emergence of virtual worlds and Web4.0 is to look for and pressure the adoption of convergence-conveying standards. There are standards of all types (security, data formats, communication protocols, etc.)[25], and all of them are part of a constantly evolving landscape. A complex landscape indeed, which some people strive to design as an ecosystem, but with some representational difficulties. It would however be fitting to mention here the Metaverse Standards Register initiative (and with it, the discussions taking place in the Metaverse Standards Forum)[26], pursuing its evolution, in 2025, towards more effective standards. In particular, as reclaimed by the founding text over the virtual world topic (see section 1.1), we consider important to stress the repeated demands for more efficient interoperability standards. So far, in the virtual worlds, a lot of applications are what we call “cross-platform”, meaning that they can facilitate the exchange of virtual assets across different devices, but within the same application or platform (although this facilitated exchange would have, in fact, to be systematically tested to see to what extent the claims hold).

This approach to interoperability makes it possible for virtual worlds that invest in virtuality accessible from headsets to operate their games, services, or functionalities without the headsets, which considerably enlarges their customer base, including smartphones. However, this is far from the ideal of interoperability, meaning that someone who develops interesting virtual collectables, games, or virtual events could theoretically move to another virtual world and reuse all their assets as if the two worlds were seamless. There are partial attempts in that direction through specific commercial partnerships, using for instance the same gaming engine (Unity[27] or Unreal are the favourites), and valuing virtual assets through cryptocurrencies and NFTs (“cross-chain”). However, we are still very far from real interoperability in all cases. The journey is still long and will probably will pass by partial

[25] In Task 2.3, workshop 2 of August 29th, 2024, we worked with a series of 13 standard categories, for the participants to hierarchise them by order of importance, considering the gaps they represent (see for that also the list and glossary presented in Annex II): Accessibility, HTML5, glTF (for 3D modelling and rendering), 5-6G, MPEG-DASH, IoT standards, cybersecurity standards, interoperability standards, legal standards, FBX and OBJ, Universal Scene Description (ESD) standards, COLLADA and fair practices.

[26] The Metaverse Standards Register (initially launched by the Virtual Dimensions Center, https://www.vdc-fellbach.de), is a publicly accessible database of organizations, specifications, policies, recommendations, guidelines and open-source software related to metaverse interoperability (MSF Tools), with now nearly 1000 entries. The Metaverse Standards Register helps organizations navigate the complex ecosystem of metaverse-related standards, encouraging collaboration among stakeholders and reducing duplication of efforts. The Register also highlights gaps in the current standardization landscape, enabling targeted efforts to address these areas, suggesting where urgent progress should be made.

[27] Unity, the gaming engine of Danish origin, but now developed through a US company ownership, is the perfect example of a *de facto* standard, i.e. not defined through a formal technical accreditation process, but adopted as reference tool by the industry for its qualities.

bridging steps on data format agreements, linked to specific data space cooperations, standard cybersecurity requirements for professional usages, co-creation best practices, standard protocols of men-machine collaborations, and open source components, etc. However, even these developments do not create immediately truly interoperable situations, but mainly help constitute technological or commercial alliances, (or integrate existing ones), and by getting people closer to one another, build particular governance schemes and experiment higher forms of interoperability.

As in our own Task 2.3 (workshop 2), we had to deal with that assignment (standardisation gaps) and, knowing that after that, other WPS and tasks, within the OPENVERSE project, would have to work on that again[28], we took it as a preparatory phase for our foresight duty. The result of this free movement stage is that we could examine different networks and trials in the direction of increased standardisation and reach a global perception of that field as being structured, if one can say so, by a series of attempts of centrifugal nature, and others of centripetal nature. The first dimension corresponded to the deep nature of economic competition, the other one to the efforts of the EU to help some major standards emerge, as quickly as possible. Let's recall that during task 3.1 on trends, the surveys showed that one of the limiting factors to the enthusiasm of economic players to engage in virtual world development (1 out of 7 hampering factors mentioned) was precisely the absence of reliable standards[29]. To what extent this double movement is not necessary, despite the need for more standard effectiveness and stability as required by the business players, remains an open question. In all cases, standardisation endeavours are not purely technical accomplishments. They are also political and may interfere with or on the contrary re-enforce some current dominations. In a few specific cases, like cybersecurity, for instance, reaching reliable standards will require a level of international governance that does not fully exist yet. Despite these hurdles, we must clearly progress in that domain.

3.3 THE VIDEO GAME INDUSTRY AND ITS INFLUENCE

Virtual worlds have several ancestors, but social media[30] and video games are the two most important. Video games have been around for half a century (Pong with Atari dates back to 1972!) and are still evolving. Figures are important, there are an estimated 2,7 billion video game players in the world, half of them in Asia, for a worldwide revenue of an estimated 455 billion U.S. dollars for 2024 (according to Statista). This historical depth also explains why, according to the statistics of Finance

[28] In particular : Task 6.1 « Input to industry standards", led by INS, duration M14-36.

[29] Let's also emphasise another trend worth considering, already tackled in a Task 2.3 workshop, namely the importance of "de facto" standards, as opposed to the "de jure" ones, which emerge only after a collective technical committee accreditation procedure. The "de facto" standards emerge from market success and there is no written law supporting them, only stakeholders' adhesion. For instance, in the gaming engines, Unity, of Danish origin before becoming US-based, is the champion and only two or three other ones can (hardly) dispute its dominance. The standards' arena is made of both types, although in the interoperability stake, there is no real "*de facto*" candidate, only formal and established standards (mainly OpenXR, WebXR and glTF- GL Transmission Format), everything must come from policy-supported and governance endeavours.

[30] Related to this legacy (social media), there is at the moment (2025), discussions and even in the US Congressional hearing regarding how large platforms, such as Meta for instance, could be impeded, should the group have to break down into smaller pieces, to continue to exchange data among their diverse applications, making it always difficult to evaluate whether our data are at risk or not (they seem to be at risk), cross-application data flows being one of the ways GDPR might be curbed, for instance. Data privacy, in principle, is taken care of by the virtual worlds' guidelines and should they want to sell in Europe, by their GDPR compliance, but then, we periodically end up discovering how things can be more complex.

online, the spread among the three categories, Millennials, Gen X and Gen Z, is almost the same. Gen X users are a bit older but were kids when video games surged. Gen Z is the first generation that was entirely born in the digital age, and there are all sorts of hypotheses on how it will drive society once they act as executives. In the middle, Millennials remain loyal to one of their favourite leisure activities.

Of course, one should not confuse video games with virtual worlds. Still, it is worth stressing that video games were instrumental in **technologically preparing the ground** for virtual worlds in several key ways:

- **Graphical Realism and Simulation**: The development of advanced 3D engines (e.g., Unreal Engine, Unity) in gaming directly enabled realistic virtual environments, later used for metaverses, VR platforms, and training simulations.
- **Networked Multiplayer Infrastructure**: MMORPGs like *World of Warcraft* (2004) demonstrated how millions of people could interact persistently in shared digital worlds—a critical proof-of-concept for today's virtual social spaces.
- **Economies and Digital Goods**: Gaming introduced the idea of **virtual economies**, with in-game currencies, rare items, and digital property rights—elements now central to discussions about virtual assets, NFTs, and metaverse business models.
- **Social Structures and Governance**: Games like *Second Life* (launched 2003) blurred the line between game and world, with self-organized communities, user-generated content, and emergent forms of digital governance that prefigure today's decentralized autonomous organizations (DAOs).
- **Immersive Technologies**: Gaming companies were among the first to invest heavily in **Virtual Reality (VR)** and **Augmented Reality (AR)** hardware and software, driving down costs and expanding technological capabilities that would later be adopted for broader virtual world applications.

In this context, virtual worlds, as we study them and try to foster them to play a significant societal and economic role, only represent a tiny fraction of XR products and services, which are already about one-tenth of the whole video game market. However, the entire development of the industry boosted technology at all levels, including hardware and software, created graphical and even cultural references, and continues to play a traction role for many other digital segments, including virtual worlds. They also were the first ones to really explore the blurring between the physical and the virtual and created the 3d immersivity and persistence at the level it is today. Now, it is true that there are controversies with video games, and similarly, some of them also concern the virtual worlds, which are of a gaming kind; so far, they are still a majority.

There are pros and cons and paradoxes. Among the pros, worth mentioning is the call of the World Economic Forum, which in 2021 (Brambilla and Maier-Lentz) and 2022 (Simon), explained how video games were good for both the mind and the economy. However, there is even better than that: studies that relativised the bad reputation which had been accompanying the history of video games. Shoshani and Krausfopf (2021) demonstrated in a convincing survey that Fortnite, stemming from the wrestling root with its Fortnite Battle Royale (from Epic Games, 2017), in which the goal is to kill other players' avatars and be the last survivor on the island, several studies have shown that this can lead, paradoxically, to cooperative and what is called " prosocial" behaviour. On the positive side, also worth mentioning is that some of the virtual worlds we have analysed can be considered as kinds of training

courses in their particular specialties, as identified in our Key Concepts in executive summary. Some virtual worlds, e.g. the Vietnamese **Axie Infinity** for the low-income users and the Australian **Illuvium** for the more tech-savvy users, build on the blockchain and the cryptocurrency universe a quite elaborate uptake perspective (not to speak of Chinese virtual worlds, tied to some of the digital Chinese giants). Some others, such as Highstreet, could be envisaged as a boot camp to learn the basics of commerce. This reading level of what the virtual worlds encompass is worth extending to other characteristics (**The Wild** in the construction and urbanism sector, **EcoMuve** in ecology, for instance). Let's also stress that there are virtual worlds which have become true specialists, like **LearnBrite** or **Virti** for educational purposes, but they somehow depart from the gaming perspective. This is only a part of the bigger picture. When considering game-oriented virtual worlds, there are many others that are excellent for education, art and culture, socialising and virtual events, community activities, and professional simulation.

These are a set of qualities and features we have already examined in Task 1.1 and which will have to be part of the scenario design. The dark side exists, too, and the same Fortnite has also been subject to fines, in the US and Ireland, for inducing players to "pay to win" (which is a more serious step above the "pay-to-play or even the play-to-earn" objectives). Many other gaming-oriented virtual worlds, and even MMORPGS (massive multiplayer role-playing games), constantly struggle between the striving to attract and retain players and make them buy the widgets allowing them to stay afloat (the "freemium" business model, starting as free, but then…). Content moderation and precautions against cyberbullying are also part of the ordinary activity of these successful platforms (among them, of course, we find the 17 ones we have identified as the most popular virtual worlds in our analysis of Task 1.1). Still, there are so many players, and virtual worlds are so tightly linked to the development of video games, culturally and technologically, that we must keep our minds open. There are also the good and the bad; no one knows who will eventually win. The debate is that for some years, despite scientific studies or even maybe thanks to these studies, and the policy-level protection for children and consumers, there will still be people who consider only addictions and mental health issues, while others tend to highlight the positive skills acquired in the gaming activity.

3.4 THE HEADSET QUESTION

Headsets have been associated with virtual reality for more than 30 years, and after all this time, one would expect that this technology would have arrived at its maturity. The truth is: yes and no. Yes, in the sense that it can already perform at a fantastic level in terms of sensorial perception of immersivity. But it is still short of a truly complete success. For demanding applications, cables are still needed, there is a latency which seems complicated to resorb and can still provoke nausea to a lot of users, and there is an evident tiredness when it comes to using a headset for an extended period of time, partly since the perceived 3D environment is not exactly the same as the one we are familiar with. There is also the cost of the device, which explains why so many virtual world developers offer cross-platform options to get more users and customers. If we follow Joseph Alsop, authoring for Statista (*VR headworn device sales 2023-2028 | Statista*), in 2024, unit sales of virtual reality (VR) headworn devices were expected to amount to 5.89 million, rising to 6.73 million units in 2025[31]. Forecasts suggest that

[31] We are here referring only to those headsets dedicated to virtual reality (excluding mixed reality and augmented reality devices, for the moment, which we do call headsets, as they tend to appear as glasses, with a see-through capacity, as we shall see later in this section).

by 2028, VR head worn device sales will surpass 9.5 million units[32]. This means that the market is increasing but remains a niche market, far from being the driving force behind the future of virtual worlds.

We can hope the technology will improve, but prices will likely remain high as there is also a fight for top positions. The photorealistic rendering costs more regarding accessible raw computer power and hardware quality. The debate: despite the periodic assertion from virtual reality developers and hardware makers that the nausea issue is diminishing, the headset components[33] will continue to improve and progress, becoming more and more attractive, but most of the virtual world progression will have to come from other angles and triggers.

One key threshold in this race to complete 3D immersion is the social dimension, with on the one hand the difficulty (still), and the cost of producing truly socially interactive 3D environments (it works and can accomplish what seemed for a long time impossible, but we are not in full social interaction mode yet), and on the other hand, the quest of lighter types of headsets, getting closer to ordinary glasses, and therefore allowing for social interaction in "see-through" mode. We are not there yet either. We have experienced in its time the Google Glass solution but even though it was designed to allow for some social interaction, if one wanted to consult specific information on the small display, he/she would have to stop, do that, and perhaps consider that there were people around, but hardly be capable of doing what we ordinarily do, namely engage in social interactions without restrictions. Virtual reality will allow doing that at a distance and with multiple people, but we are targeting the 2040 horizon more than the 2030 one in terms of sustainability and efficiency.

This Google Glass step did not work, but it currently seems to boost, again, the motivations of several makers to reach a satisfactory level of service and performance in that domain. At a moment when META is pouring dozens of billions into smart glasses' R&D (on top of already engaged partnerships with Ray-Ban[34] and Orion, this topic is to be followed with great attention. META is not the only competitor in the quest for the Holy Grail (we are not there yet). For instance, Luxottica has confirmed that new versions of Google Glass are in development, aiming to improve battery life, sound quality, and overall aesthetics, appealing to consumers by integrating cutting-edge technology with fashionable designs[35]. In the domain of mixed reality glasses, the recent Apple headset Vision Pro created new hopes, particularly in professional applications, and it seems that it delivers for that segment, especially after Microsoft stopped the development of HoloLens 2. As for Magic Leap, with its release two and its lighter weight technology, despite huge investments, it is still not getting the expected success and is now trying to collaborate with Google. Similarly, XRS Space, from Taiwan, has announced significant innovation breakthroughs in the metaverse and has announced a cooperation with META. However, we are still waiting (XRSPACE to Accelerate Taiwanese Metaverse Growth - XR Today). The direct social dimension of virtual reality (in particular when it comes to seamlessly integrating people from the immediate surrounding environment into the virtual working space) is still in its infancy, technologically speaking, while mixed reality capacity for specific industrial needs is

[32] We also have to mention that during the COVID epidemic the headset sales increased, and then regressed, a rather normal evolution, and recently seemingly going upward again.

[33] With the headset, there is a full toolset to consider: handles, or the joy-con variation (from joystick and consoles), as well as other haptic resources, lidars and kinetic systems.

[34] See for that, for instance: Meta Enhances Ray-Ban Smart Glasses with New AI Features and Design Updates

[35] See for the latest notifications: Google Unveils Next Phase of AI-XR Integration with Android XR

progressing and making its way up, but with its professional specificities (e.g., Apple Vision Pro, for the moment).

One of the experts, in the Foresight process, expressed the idea that the consumer electronics threshold (here, headsets) could trigger XR and virtual world developments and constitute, in fact, from the consumer market to broader scale applications, a generic innovation model for the shaping of virtual worlds in the future. In support of this observation, he mentioned the example of Porsche using Apple Vision Pro in a mixed reality application. However, we do not see all the consumer electronics which would be available for this process to take off, other than all those already developed and used in the XR arena today (see also the next footnote, proposing a brief assessment on that trigger). This type of deployment scheme is likely to expand, of course, especially with XR applications, but the question is whether it may constitute a mainstream track for innovating in the virtual worlds or more of a co-construction of different factors.

To support his hypothesis, the same expert mentioned the case of Nvidia, which eventually ended up in the Omniverse virtual world. The AI market, in his opinion, is clearly stemming from the consumers' demand, particularly the production of graphic cards. Let's observe, however, that this example may bear several different interpretations on what triggers what and why. In the expert's view, the only concern in this innovation theory is leaving enough time for the necessary market incubation process (or "iteration cycles", according to another participant) to occur. Evolutionary economics developed another approach, more Darwinian, considering that many such attempts, whatever the time the iterations (or R&D rounds) envisaged, do not succeed. Only specific markets and socio-cultural environments select some of these processes to go through (based on pulling factors rather than the sole pushing efforts) and diversify to new technological and market options. This debate has been around for some years and will most likely continue. Thus, is it the development of consumer electronics that produces valuable adoptions in the industrial world or the needs of the industrial world, with clear value-added performance and due ROI, which generates the development of specific devices and interfaces? The chicken or the egg?

One of the experts, quite involved in the virtual developments, expressed the same view as his colleague, with different words: *"there's a belief that industrial applications drive innovation, and I actually do believe it's the opposite",* basically confirming that these markets tend to be generated by consumers' purchases. Whatever this debate eventually triggers, let's nevertheless stress that the developments allowing the representations of 3D environments in 3D displays, unique or multiple, flat or folded, with sound-seeing effects, and all the means, protocols, devices and standards facilitating this process and their efficient implementations into concrete services are essential progress tracks to follow nowadays.

To summarise, the headset issue encompasses several interesting debates. One concerns its possible large-scale expansion as the principal mode of progression of virtual worlds, or for quite a while, on the contrary, staying a stimulating niche, but to a large extent, translated into cross-device implementations of the virtual worlds. In our study of the 75 virtual worlds (OPENVERSE Task1.1), we noticed that nearly all virtual worlds, to have enough users, went for cross-platform variants. Another one concerns the innovation dynamics are the few examples proposed from consumer electronics as triggers for some of the markets we are now considering a mainstream trend, or Darwinian exceptions, with deployments most of the time due to a plurality of co-factors when they take place (a lot of innovation fade away or encounter more competitive substitute). Then, in the third debate, there is

the question of industrial uptake of XR or virtual world applications, as well as the supporting devices. These developments have already caused the end of some innovation journeys (Hololens, but before that, many others which also tied themselves in the mixed reality domain, which requires a lot of costly calibration, monitoring and training before any ROI), with significant value added when the widget finally works, but not of easy access and implementation. We should not avoid confusing this with consumer electronics. We are rather in an industrial ecosystem, whose fine-tuning requires time, money and expertise. But we cannot exclude that, just the opposite of what was suggested by other participants, in some years, these developments will become cheap enough, of easy uptake and customisation, and therefore, effective candidates for mass consumers' applications in the XR and virtual world arena.

3.5 THE GENERATIONAL STAKES

The sociology of virtual worlds is remarkable. Of the 75 virtual words we analysed in Task 1.1, many related to gaming, entertaining, and virtual asset creation. As a matter of fact, a majority of virtual worlds was tuned to seduce classes of age from young to very young (from 35 to 12, let's say), corresponding to the core of Gen Z and extending to the Millennials. This generational focus involves several issues, one of them being whether the older generations, and in particular the baby boomers, sixty and above (30 % of the population in OECD countries), could be considered part of the plan. Another issue is that there seems to be a type of culture emerging (something much beyond the notion of literacy), with its codes, aesthetic criteria and values (we already evoked some of it with the Fortnite paradox), which becomes so prevalent in terms of numbers (of users, of creators) that some multinational companies have started, for the past two years at least, marketing-wise, to try to grab their attention; and with more to come, if affinities. The spread of the virtual worlds we analysed in depth in OPENVERSE Task1.1 shows this flexibility. Many are important in the gaming and entertainment spaces, but there is in reality a diversity of possible connections with promising open and creative avenues. This flexibility of assignment, purposes, affordances or market orientations, as one wants to call it, is reflected in one of our maps, produced within OPENVERSE Task1.1:

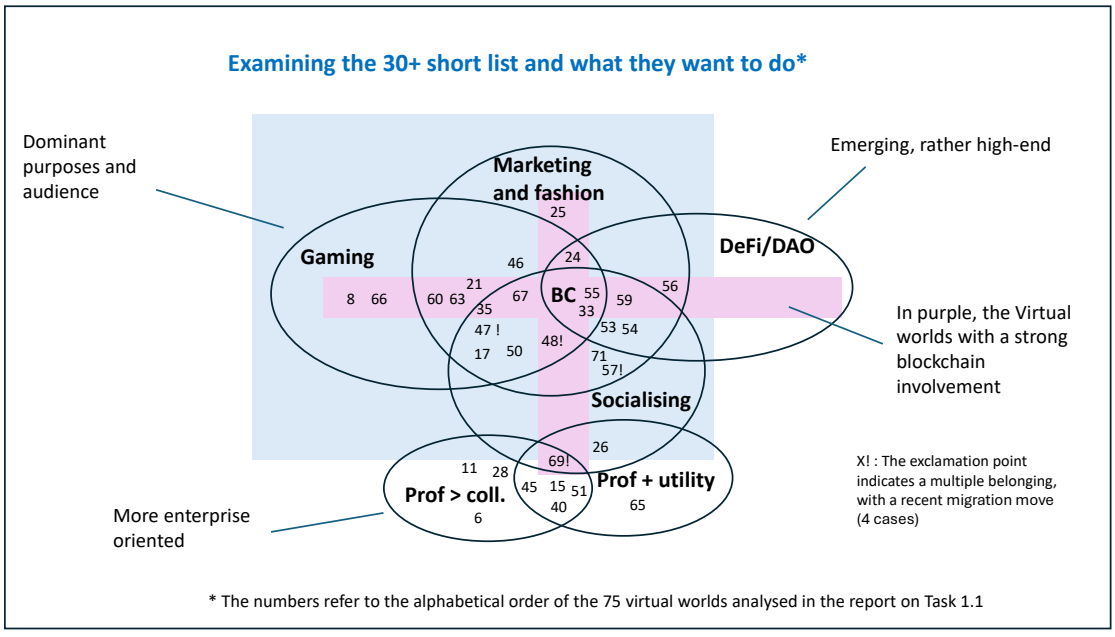

Fig 7: The 30 Virtual worlds' topological spread we retained as candidates for further activities (T1.1)

This diagram's topology aimed to identify what the selection of 30 virtual worlds to which we applied our Analytical Framework (10 dimensions, 29 dimensions)[36] actually does, in terms of main vocation for each virtual world. In blue, the space where the majority of the virtual worlds operate (more than 2/3). In the purple cross, those that have a strong blockchain involvement are listed. It is interesting that the gaming purpose can also be shared with marketing and fashion, and, of course, socialising, with virtual events and virtual community activities. As we shall increasingly see in this foresight process, **this continuum of options is a crucial factor** (see section 4.5.1). In the bottom part, we can find the more professional-oriented virtual worlds of our 30 selection, more of the B2B2C kind, and which do not have a clear objective with the above purposes, only partially intersecting features[37]. We do not have figures concerning the sociology of this difference, which leaves room for further research. Still, the graphical line, the type of functionalities, the proposed cultural tone of the virtual world in the blue zone as opposed to the purposes, style and working mode of the more professional-oriented virtual worlds suggests a 10-20-year gap between the two categories[38]. The culture we are talking about here goes very deep into a lot of the functioning in society. Henry and Shannon (2023), in their book on the Virtual Natives, show multiple clues concerning how this transformational practice takes place. Digital and virtual are part of everyday life. Gaming is a way to exchange tips and perceptions, share pleasurable experiences, and, more than that, **get accustomed to a more fluid identity**. **Users learn how to collaborate, solve problems, understand and evaluate their trial-and-error journey**, and consider themselves individuals with personal interests or part of communities with higher possible yields. In this evolution, they seem to claim that the borders between statuses are blurring: from users to experts, from users to creators, users in one environment, creators in another one, experimenting as a mode of discovering the world and sharing impressions. Gradually, efficiency comes, and as there is more and more AI in the creation process (as we shall see with more details in the next section), the "agentivity" shift is not far, with new capabilities, individual AND collective.

As if this evolution wasn't deep enough, different authors[39] emphasise how in virtual worlds, memory identity, which can be defined as **the personal and collective sense of self that emerges through the interplay between one's digital memories and the narrative environments in which they are embedded**, is shaped by the content users create or encounter, and how platforms algorithmically curate, prioritise, and contextualise that content. It reflects how individuals are perceived by themselves and others through the digital traces, commemorations, histories they inhabit, and challenges that they confront and gradually transform their digital memory. In immersive contexts, memory identities may be continuously reconfigured by interaction with avatars, AI agents, and dynamic storylines, thereby rendering identity a more fluid, situational, and computationally influenced construct. Its protection involves recognising that digital memory is not merely archival but constitutive of subjectivity, making ethical oversight and design integrity paramount. From this perspective, the distinct ways younger generations acquire information and communicate, gradually

[36] Let's recall, as it was explained in the section 1.7, that we started with a sample of 75 virtual worlds, applied them a series of criteria to diminish that number to 30, among which the stringent one of GDPR compliance, meaning that all 30 virtual worlds we took time to analyse in detail are GDPR compliant.

[37] They are more oriented towards man-machine collaboration, digital twinning agency, distant maintenance, efficient collaboration, training of trainers (including with the help of AI), offering a full SDK environment for developers, etc.

[38] We have to stress that the ROI of professional-oriented virtual worlds cannot be calculated by the sole number of users or screen time spent in particular applications, it is slightly more complex, just as it is to implement, calibrate, make efficient and customised even the most brilliant mixed reality application.

[39] See in particular Bailey al (2012), Bachleitner (2022), Bonnail et al. (2023), Orianne & Eustache (2023). Bampouri et al. (2024), Mandolessi (2024), Vardanyan et al. (2024).

adopted by the older generation[40], are not merely methods of accessing and managing informational resources. Instead, they represent a lifestyle, a culture where the boundaries between physical and virtual activities increasingly blur. In this fast-evolving context, a key question is emerging, or rather, an open debate, with critical, impactful consequences for the future of virtual worlds.

This debate centres on whether the emerging habits of younger generations—particularly their engagement with social media, video gaming, and virtual worlds—will evolve over the next 20–30 years into a widespread way of life, or at least a significant part of it. Alternatively, various obstacles may hinder this transformation, such as mental health concerns, the impact of disinformation, the spread of hate and biased narratives leading to mass confusion, and the increasingly blurred boundaries between physical and virtual realities, with positive but also problematic challenges. Additionally, the potential erosion of identity management frameworks could result in oversaturation and counterproductive effects. These are only a few of the changes taking place, although for more professional virtual worlds, the required qualities may be slightly different, with more specific co-creation processes.

As a general comment, the skills that are being acquired nowadays by entire classes of age thanks to these flexible and explorable environments, which we call virtual worlds, start to become a societal threshold and a competitive agenda, most likely to permeate other domains. In other words, the open debate is between those who think that non digitally playing individuals will sooner or later disappear, with the whole world assembling around this emerging mainstream culture, today associated with gaming and socialising, and those who think that the skills that are being developed in that dynamic will be helpful to many other cognitive, emotional and social challenges of tomorrow, but within a series of distinctive adaptations, themselves creative and in principle, human-centric, and maybe, also, regulatory arbitration.

3.6 AI AS A SUPER BOOSTER?

AI has been developing fast and in a very competitive context. While we were paying attention to the "metaverse disputes", an escalation in the digital investment took place to boost Generative AI solutions, which rapidly improved their performance and increased the outreach of what they were capable of doing (the diversity of tasks, level of complexity, innovative ways of conversing with them through prompts, etc.). When we analysed 75 the virtual worlds at the menu of Task 1.1, one year ago, AI was mainly used by the platforms (and maybe only half of them with explicit claims or explanations on this) to optimise their functioning, swiftly adapt to changing regimes (number and types of users, types of challenges), with varying algorithmic rationales, and also to support some functionalities to demanding users, making the whole virtual world functioning more dynamic. The changing reactivity of the virtual world towards how users tend to behave would be impossible without AI. Let's take an example among many: **Spatial**, a US virtual world. It used AI to facilitate avatar creation, facial expressions, movement management, spatial-audio processing, content moderation, and AI-driven analytics to understand user behaviour and optimise the platform, providing, in particular, insights on how spaces are used. Most of this AI-supported capacity stayed internal to the platform management, and only part of it would be accessible to creators, for instance, to optimise their customisation endeavours. Let's add that Natural Language Processing could be used to help users with specific

[40] Worth consulting, in this perspective, is the global consumer survey by Durand-Hayes Sabine et al. (2023), which clearly shows that the habits of the young generations tend to spread "upwards."

disabilities and operate an internal chatbot. Some virtual worlds, like **Remio** (but not the only one of its kind), could also provide recommendations to the user, according to their profile, how they played, their performance, and their expectations.

The capacity of several virtual worlds to make "non-playing characters" (NPCS) behave intelligently to interact with human players is, of course, essentially due to the use of AI. As a recent edition of the MIT Technology Review put it: “AI is changing how we play” for users and designers (AI-powered design), for creative tasks and asset management duties[41]. Now, with the more recent evolution of AI, the inclination of virtual worlds to use AI for their own functioning and attractiveness increases, and new options have emerged. The first one worth mentioning is the capacity of some virtual worlds (let’s mention for this in particular **Virti**, **Engage VR** and **Arthu**r) of allowing the users to train avatars to make them behave according to their needs, a functionality very useful in training activities. Then, of course, the possibility of using AI to create images, voices, modify the look of characters, past, existing or non-existing ones, and even now producing short videos, has emerged and will not stop expanding its outreach and level of performance, as well as its easiness of use for ordinary people (just as the “low code” or “no code” options already proposed by a few virtual worlds). In other words, virtual asset creation and even game creation will be facilitated by AI to an extent that is still difficult today to conceive. Some combined moves and manoeuvres are already perceptible such as the importance taken by the NVIDIA chips for Gen AI developments and their potential usage for the Universal Scene Description (SDF) format, which quite logically gives already some advantages to a virtual world like **Omniverse**, property of NVIDIA, and with it, all their privileged partners[42].

We could also add current transitions, like the bundling of the AI with existing platforms’ services like Gemini and Google and Microsoft and Copilot, most likely to appear in virtual worlds any time now, and of course the access of AI services form smartphones, showing the cross-platform importance which we already stressed for several virtual worlds.[43] This is the current stage of the evolution of virtual worlds regarding the use of AI. Still, much more is being prepared, with three main innovations: 1) the possibility to combine or mingle in real-time different data sources (text, still image, voice, video), 2) the development of Reasoning language model (RLM), in the wake of the DeepSeek surge early 2025, and 3) the “agentivity” (AI acting as an autonomous agent, with a programme of its own to be defined), that is being elaborated from these various learning dynamics. This innovative set of capacities can also be conjugated (like it is already partly the case) with some of the blockchain technologies (NFTs and smart contracts in particular, but also the management of crypto-based virtual assets at large, and soon maybe DAO).

Finally, let’s stress that emotions’ analysis and simulation will further evolve in the coming years (they are now in its infancy), and more sophisticated virtual avatars will come, capable of mimicking human personality traits and even fine-tuned emotions. This evolution triggers at least two open debates.

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[41] MIT Technology Review Vol 127 (4), July/August 2024.

[42] Let’s stress that the much-demanded NVIDIA chips specialised in AI support are selectively distributed (for instance, Swiss players, scientists, and corporate actors have no access to these chips for the moment).

[43] Let’s note here that one of the participants, extremely well introduced in the virtual world arena, considers that the AI factor has become so important that the only chance we have is to go for virtual worlds entirely made by AI. Whatever is the time proximity with that assertion, it raises a number of fundamental questions: do we want that, can we avoid it, how about competition between AIs generating competing virtual worlds, who eventually chooses, for what usage and meta-geo-economic competition, and how about the human oversight, if any, who can take advantage of such an overall development, etc.?

The first one concerns a question which at the moment has no answer: will these augmented capacities of the AI-supported users stimulate or, on the contrary, diminish the motivation to engage in creative activities, understanding that the production will become even more massive and with tones and style not entirely “proprietary”?

The second one is more worrying: will this super-boosting support generate situations in which the blurring between the physical and the virtual extends much beyond what is currently the case, and with the creation of communities having their own culture, rules, goals and impact? It is a strange question as after all the Web4.0 concept encourages this blurring, but then, is it likely to be contained in the perimeter of the virtual worlds that were used or can it extend to meta-environments using opportunistically several platforms and their characteristics “as a Service” to build worlds of more autonomous nature?

There is a saying spreading regarding AI that AI will not replace people, but that people who do not know how to use AI will be replaced by those who do. In the case of trans-organisational settings capable of capturing functionalities and resources where they are (and interoperability can only facilitate that evolution), to use them in a little regulated way and in spaces that are essentially virtual (no specific territoriality), will it still fit within the value driven objectives of the EU in the matter? This development could lead to, for instance, a considerable enhancement of digital commerce within the virtual worlds, with AI-powered bots helping to manage businesses, transactions, and customer interactions, even for little-trained or legally unresponsible players. The first question is for 2030. We are undergoing a fundamentally experimental situation, and the objective for that phase is to keep all the factors encompassing the regulators' decisions and the human oversight under control. The second question is more for 2040, but may convey signals that should be addressed much earlier. This is precisely the topic of an article in the MIT Technology Review of July/August 2024, by Niall Firth: “Games without limits”.

3.7 THE ENVIRONMENTAL ISSUES

Here, the problem seems to be relatively straightforward. There are arguments in favour of considering that virtual worlds have environment-sensitive benefits, and others showing that they also tend to deteriorate both the climate and the pollution level. Each one may choose what he/she prefers to believe and focus on. The debate is open and often expresses both sides. This is, for instance, the case of the seminal study produced by the JRC in 2023 (De Hont et al., already mentioned: 38-40), which was the first to inaugurate this balanced approach to the environmental challenge that virtual worlds have to cope with. Things are somehow complex (i.e. multi-dimensional, with dimensions which do not compare and often lack clear metrics). Still, the surveys, reports, scientific articles, and books abound to show that the carbon and hydric footprints of the digital in general increase steadily. In the years to come, they will reach a significant part of the total energy consumption (estimates vary, for the time being between 4 and 15 %).

Most observers (see references in the footnote) stress the worrying speed at which the contribution of the digital to the overall climate pressure increase. On the positive side, travel saving seems to be the main argument proposed, a minor one being the potential increase in manufacturing productivity (where training, distant maintenance, and digital twinning can indeed provide value, of economic but

also environmental kind)[44]. We also hear, often, about the virtues of several virtual worlds to help educate young people about ecological issues as a key contribution (building awareness and giving access to essential explanations), and it is not rare to see some of the virtual communities generated and managed by virtual worlds promoting environment-friendly solutions.

There are also here and there some vague claims that virtual worlds are in line with the UN SDGs (but how and with what kind of concrete channels, experiments and metrics) or that promote well-being and quality of life (this needs to be scientifically grounded, not just invoked). On the negative side, it depends a lot upon what we identify as being the perimeter of virtual worlds: as a specific segment of the digital sphere without implications with the rest, or on the contrary, participating and contributing to the environmental load and the carbon footprint in its own terms[45]. Virtual worlds incorporate more and more AI (which is right now the principal increase factor of energy consumption), many of them also include streaming options, another important carbon footprint increase factor, and there are also all the material dimensions (headsets, cables, handles, smartphones, tablets and computers, game consoles and other merchandising items and collectibles) and its grey energy issue and de-pollution challenges.

We should add to that the growing trend of blockchain-related services, the third significant carbon footprint increase of the digital sphere[46]. Moreover, there is the growing attractiveness and addictive schemes behind the consumption of virtual worlds, something essential, which has been studied in other domains (such as mobility issues in particular), namely what is called **the rebound effect**. We are told that a lot is being done to help decrease our environmental pressure (we have the impression that we travel less, maybe, and that for the blockchain and the AI some co-generation solutions develop everywhere[47]), and at the same time we hardly perceive that our consumption increases and the number of energy consumption contributors and ways of spending energy through the digital also increase[48]. Big players consider building nuclear plants to service the energy outflow of the data centres, and this particular type of infrastructure flourishes everywhere, with competing projects of gigantic size. As this part of our consumption is almost invisible to us, we may think that if we can interact with more people without moving too much, the balance stays on the right side, while we are using more and more digital services and generate data to move and store. This induction process is

[44] In addition, as the Draghi report (2024 b: 67) recalls it, digitalisation can also bring some decarbonisation (even if his report does not speak specifically of virtual worlds. See also for that Muench et al. (2022) on the possible convergence of the digital and ecological transitions.

[45] We may make this distinction as the carbon footprint directly addresses the question of global warming and its consequences. At the same time, the environmental load also encompasses diverse polluting effects, with local or global implications.

[46] A few references are worth mentioning to get an idea of the variety of this much-debated field: 1. Although it is published in French, for the scope and depth of his analysis, see Pitron (2023), 2. Sharma and Dash(2022), for the general view on the digital and its impact, 3. Skare et al. (2024), with a more nuanced perspective, also highlight the efforts that can be done to mitigate the environmental burden and finally, 4. for analyses addressing specifically the climate challenge conveyed by the virtual worlds, Stoll et al. (2022) and Pellegrino et al. (2023).

[47] It happens, but not everywhere, and the estimate of how the gains compensate the energy spending increase is still to be done with rigorous metrics and consensual methods.

[48] The rebound effect constitutes a paradox. It is to a great extent “because” most users may consider that they are “saving” something (e.g. in our case, consuming less since they are travelling less each time they have an online distant collaboration), that gradually, the conditions for an overall carbon footprint increase emerge and then expand.

precisely what is the rebound effect (which has been studied for over 30 years, including in digital developments)[49].

However, as a lot of innovation can still take place and as there is still no a high price put on the use of digital services, in environmental terms, at least for the moment. However, the negative impacts of climate warming are little likely to magically disappear (droughts, floods, mega-fires, respiratory problems, loss of economic capacities, growing unwillingness of insurance to pay for recurrent or predictable environment-related damages)[50], and this debate may soon become quite acute. Thus, even though the time for urgent measures regarding the digital footprint has apparently not come yet (people can be satisfied with the idea they save trips by collaborating at a distance), for the EU, and this can be considered as part of the Green Deal commitments, we may see that debate being increasingly exacerbated as we get closer to the 2040 horizon. Globally, as the regulation of digital usages for environmental reasons is not really constraining yet, we can see this problem as a half-full / half-empty glass, from which each one can choose his(her side. This will be reflected in the scenarios.

3.8 DIGITAL SOVEREIGNTY, A GROWING CHALLENGE

The issue is very timely, but in the last 18 months, the Draghi and Letta reports strengthened our perception and at Inspiring Futures, we have worked on this problem since the beginning of the OPENVERSE project and even before[51]. What are we talking about, however?[52]

Digital sovereignty conveys specificities that similar concerns applied to other domains (medicine, energy, food or other forms of sovereignty) do not necessarily embrace with the same magnitude or outreach. The reason is that digital technology today touches all domains of activity, with generic and cross-cutting applications that are not sector-specific. It therefore has implications in the following fields:

- **Economic**: facing giants and players engaged in international domination strategies, with their level of control on data flows.
- **Security**: We depend upon the goodwill of others to defend ourselves and keep our informational landscape free from adverse narratives and fake news.
- **Cultural-ethical**: There is a broad cultural battlefront on which we seem to be forced to defend specific values that have taken decades (and more) to establish.

[49] Let's acknowledge that this debate has been fully recognized within the EU strategic reflections, for instance, in 2025 with the key question "the digital, good or bad? (Going digital – good or bad for the climate?) and already in the Twin project, which was mentioned (Muench et al. 2002), in which Inspiring Futures has participated.

[50] For that reason, we allow ourselves to make the hypothesis that the current climate skepticism and retro-pedalling policies regarding climate warming, in the medium term, may resurface with even increased emphasis.

[51] Let's recall that the Digital Compass, with its four cardinal points (Skills, Government, Business and Infrastructure), was introduced by the European Commission on March 9, 2021 and improved in 2025. It outlined the EU's vision and targets for digital transformation by 2030, aiming to enhance digital sovereignty and promote a human-centred, sustainable digital future (see Digital Decade - Policy programme | Shaping Europe's digital future and also LEAK: Commission in bid for EU data sovereignty with digital decade targets - Euractiv). The 2025 version also emphasized the need to reduce excessive technological dependencies.

[52] We will not discuss here some of the 2022 and 2033 debates we had on whether the term sovereignty was a bit too harsh and whether we should use other notions, such as independence and autonomy, instead. Recent international developments completely changed the status of this semantic distinction, and we will stick to the idea of sovereignty.

- **Environmental**: negationist narratives and corresponding environmental policies are striking back.

Having depicted this dramatic situation with only a few lines, it is worth stressing, as a counterpoint, that the EU has not waited for this critical stage to act, and on the contrary, it has been highly active, in particular (with here only a sample of what has been undertaken) :

- Specific measures to protect EU countries, economic players and citizens in the digital sphere (Berlin Declaration, Data Act, …).
- Regarding AI (the AI Act).
- Protecting privacy rights (GDPR, a great success).
- Supporting fair business (DMA, DSA[53]) and IPR correctness

- Converging with UN-SDGS in many ways, with even links between the digital and the Green Deal

The complete list of measures, regulations, recommendations and programmes to support a EU and both performance and value-sensitive approach to how the digital should evolve, as outlined in the Digital Decade claim, is impressive. It is primarily defensive, with, however, for the various sub-segments, interesting proactive and "offensive" (or "propositive") initiatives. The idea behind promoting Open and Human-centric virtual worlds towards the Web4.0 is of that kind.

These endeavours, however, are far from solving the problem of digital dependency. Let's see now why and how the situation is still a source of worry.

First, a series of challenges remain open and unsolved, even with the EU's positive and determined efforts: cybersecurity and digital trust, disinformation, economic spying, and political interference.

Then, there are long-term dependencies to cope with: military systems (e.g., the F-35 contracts), the time it will take to design and construct substitutes or high-level autonomous alternatives to e.g., Google (search engines), central operating systems, leading social media platforms, NVIDIA chips, and Starlink vs. IRIS, sending us to a time horizon of 2030 and beyond.

To a large extent, this remark is valid for several digital sub-segments :

- Chips, key digital platforms, smartphones, rare earths, digital champions, AI (a manifold domain with very uneven investments)
- We can build an EU cloud and edge continuum (it will take time[54] and involve hard choices as the substitutes still tend to lack, although some solutions already exist. However, we need to

[53] Among many other objectives, the DSA aims to regulate the monitoring of algorithms. This essential factor could determine the distinction between a 'pay-to-play' and a 'pay-to-win' business model and its underlying incentives.

[54] Among different attempts at building sovereign solutions, worth mentioning is the EOSC Strategic Research and Innovation Agenda, or SRIA, whose objective is to define the general framework for future research, development and innovation activities in relation to the European Open Science Cloud (XRSPACE to Accelerate Taiwanese Metaverse Growth - XR Today. For a true EU-based and maintained cloud, we can of course mention the Gaia-X initiative, launched in 2020, with the support

ensure that all member states follow it. It should also include data transit (end-to-end) and all the associated infrastructure.

- Except for the defence layer, the satellite coverage is quite up to the job (Gaia, Copernicus, Galileo, etc.), and we are still waiting for IRIS and an actual « space defence » capacity. Let's observe diverging perceptions on whether the EU is on the safe side on the satellite question.

In this troubled time, a quadruple requirement seems urgent to consider :

- Urgencies and strategic vision (sufficiently anticipatory) must converge.
- Political cohesion and from there, new alliances as needed.
- Complementary and synergetic investments (vs. fractal and redundant/competing egocentric national interests)
- Building on areas of excellence (we will come back to this in section 4), we can identify the following assets to promote:

    - Science, industry, and science-industry partnerships, open source (of complete applications such as platforms but also of partial components) and open innovation tracks, innovative sectoral and community-driven developments, sustainability considerations in assessing, promoting, and financing novel initiatives, and skills and meta-skill valuation.
    - Data spaces and all the trusted intermediaries and innovators who make these initiatives valuable experiments and collaborative assets[55].
    - Work on gaps, but in support of **key industrial strengths** (XR and virtual worlds, especially for professional applications, interoperability standards, AI of different kinds, and bypassing in concrete sectors the search engine deficit).

As opposed to the loss of sovereignty, we would like to stress the idea of resilience, meaning the capability to develop and nurture, to work simultaneously on all these levels, in all these directions, to cope with all these stakes, and to learn together and quickly.

The debate, as this section is about open discussions, is that in the area of virtual worlds, we have no other way than to engage in an ambidextrous activity:

- On the one hand, we need to develop EU-based and maintained virtual worlds and at least strengthen those who fit this qualification, with orientations that comply with some of the deficits evoked in the above paragraphs.

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of important European telecom companies (Gaia-X-Brochure_Overview_February_2025-v2.pdf), and Virt8ra, launched in February 2025, (The EU Tech Industry Joins Forces to Launch the First Sovereign Edge Cloud for Europe) meant to provide Europe's first sovereign edge cloud infrastructure, with low-latency capacities useful for smart trains, remote surgery and wild fire monitoring, for instance. To get an idea of how advanced the Gaia-X initiative is (quite promising, through its hubs, and the lighthouse projects and data spaces): Gaia-X and Partners to Showcase Cross-Border Data Collaboration at Hannover Messe 2025 - Gaia-X: A Federated Secure Data Infrastructure and Successful completion: Gaia-X Project Tellus delivers key component for the collaborative data economy

[55] See for that, in particular Common European Data Spaces | Shaping Europe's digital future and Data Spaces | Interoperable Europe Portal

- On the other hand, to keep learning and acquiring all the best-in-class skills, we also need to collaborate with the US and Asian virtual worlds, those who comply with our values. We hope that learning and competence acquisition will soon be nurturing EU options of the same status.

In other words, the sovereignty issue cannot be solved overnight; it has to be strategically and concretely (locally, sectorally) constructed. Effective road mapping appears to be not an advocacy exercise, not just the elaboration of a wish list, but a pragmatic journey to real and sustainable changes. In particular, it involves pursuing the regulatory pressures against the big platforms' wild behaviours and the generic fighting against the extractive business model, which systematically captures users' data to build the LLM services and prolongs in the AI age the well-established practice of envisaging users as data sources.

3.9 CONNECTION WITH THE FORESIGHT PROCESS

All these debates have emerged one way or another in the deployment of Task 2.4 and, of course, its four workshops. Most of them surfaced but stayed open (unsettled) as part of the scenario making games, or as expressions complex to allocate to one of the proposed scenarios. The purpose was not necessarily to all agree and end up with consensual statements, but on the contrary, to value the diversity of opinions eventually supporting the different scenarios, as legitimate expressions of the experts' viewpoints. As time was short, it has not always been possible to elicit all these discussions towards a formal stage, as a completely coherent reflection. In fact, most of these debates will continue to exist and nurture discussions among experts in the years to come. Through their components, they have first found a place in the different scenarios we have proposed, and it will be, as needed, easy to refer to these debates further on (in Task 2.5, for instance, or in other OPENVERSE ongoing tasks).

4 POPULATING AN EU-SENSITIVE PREFERENTIAL TRACK

This chapter introduces a preferential framing for the 2030 state of the future concerning virtual worlds and the Web4.0, stemming from the most desirable features that have emerged from all three scenarios in terms of the EU strategic interests, as they were discussed in the foresight workshops, and which we can therefore call a **Meta-scenario.** Rather than prescribing a fixed and ideal future, it offers a co-constructed vision: a narrative configuration grounded in expert insights, institutional expectations, and thematic tensions identified across the preceding chapters, capturing valuable insights from all three scenarios. From this perspective, this meta-scenario serves as a policy-relevant anticipatory reference intended to guide reflection, support decision-making, and inform the design of future interventions for virtual worlds and the Web 4.0 ecosystem in Europe, particularly bridging with the further task of producing a policy-relevant roadmap.

4.1 TOWARDS A VECTORIAL META-SCENARIO: "BUILDING EUROPE'S AMBIDEXTROUS HORIZON"

By 2030, virtual worlds in Europe will become more widespread, civically embedded, **and less of a niche activity**. Rather than following a singular trajectory driven by the sole market expansion in conjunction with AI investments or regulatory maximalism, Europe has chosen a more ambitious path that **bridges technological innovation with community and sectoral needs and democratic governance**, ensuring that virtual environments enable individual and collective flourishing. This future reflects a deliberate synthesis of policy design, cultural participation, institutional foresight, and ethical pluralism, framed by Europe's values and driven strategically by a long-term requirement towards more industrial autonomy. The spaces that make up this hybrid ecosystem are increasingly interoperable, inclusive, and adaptable. **Immersive technologies are deployed in several sectors**, from education and healthcare to industrial design, digital heritage, and creative economies, but always within **context-aware governance structural support**. European users interact with intelligent agents, memory environments (a concept which we have already defined, in a prior footnote), and multisensory narratives in ways that optimise agency. At the same time, institutional frameworks provide transparency and redress without curtailing the multiple community and sector-based creative potential engaged. This vision draws directly from tensions and aspirations articulated throughout the foresight process. From some of the regulatory debates identified in Chapter 3, it embraces the principle of **proactive alignment**, ensuring that innovation is not stifled but **strategically steered** through modular, participatory mechanisms. Echoing the decisive factors analysed in this Chapter 4, it recognises that **no single model can remain static**: platform logics, generational preferences, and geopolitical conditions all demand flexible governance that evolves with technological and cultural change.

This scenario inherits a deep commitment to reflexivity and co-creation from The Architect's Dilemma as a primary source. Users are not just consumers, but **co-architects of meaning**, identity, and virtual public life. Policy-making is capable of fostering professional innovation, converging with several types of requirements. From *The Price of Remaining Human*, it absorbs a carefully delimited ethics-by-design approach, ensuring that immersive environments uphold rights and dignity without stifling adaptation. From *More of the Same Thing*, it borrows the usability and convenience of seamless integration, particularly AI and blockchain innovation, without succumbing to dependency or commodification of identity. Governance is not monolithic. Instead, **policy ecosystems are diversified and iterative**. Regulatory sandboxes, civic design labs, and public–private foresight consortia enable **institutional experimentation within secure boundaries and controlled environments, an experience and learning curve which can be shared by various stakeholders concerned by the development of virtual worlds**.

Standards are developed in open multistakeholder processes, ensuring that digital identity, immersive content, and memory rights are not governed solely by commercial entities. Trust is reinforced through traceability systems, value-sensitive design, and institutional accountability mechanisms visible to citizens, and at the upper level, translated into governance and policy decisions and part of the corresponding international negotiation interplay in which the EU is engaged. The digital infrastructure enabling this scenario is underpinned by European R&I investment, informed by critical foresight, and coordinated through cross-border mechanisms aligned with the EU's digital decade goals. As seen in Chapter 1, this future places equal weight on technological readiness and social legitimacy, making foresight not a luxury but a governance capacity. Importantly, this meta-scenario does not aim for finality. It acknowledges the risks of institutional inertia and ecological volatility highlighted in the 2040 outlook. It prepares for the arrival of disruptive agents like synthetic minds, ambient intelligence, and new material ecologies by **embedding learning loops into industrial and strategic economic needs in tight interplay with governance systems**, ensuring that Europe's digital transition remains anchored in societal deliberation and anticipatory responsiveness.

4.2 THE LOGIC AND PURPOSE BEHIND THE PREFERENTIAL CONFIGURATION

The meta-scenario presented in this chapter was not selected as a "median" outcome, nor constructed as a compromise between competing priorities. Instead, it emerged as a **vectorial synthesis**, an intentional alignment of **desirable traits and system-level enablers** drawn from across the scenario space. It results from a four-stage iterative foresight process, rooted in expert judgement, thematic deliberation, and structured scenario refinement. Building on the tensions and drivers mapped in Chapter 3 (as well as in this Chapter 4), the scenario addresses the **most pressing strategic tensions** highlighted during the workshops: algorithmic agency to identity realism, innovation regulation dilemmas, re-industrialisation needs, and cultural and economic ethics. The experts participating in the foresight process voiced consistent concern about rigid binaries: between centralisation and decentralisation, protection and openness, creativity and control.

The scenario thus offers a strategic deployment and **governance grammar that is plural and evolving**, neither prescriptive nor unbounded. It reflects the institutional aspirations of the European Commission outlined in sections 1.1 and 1.5: strategic autonomy, value-based governance, and inclusive digital transformation. It aligns with the high-level principles articulated in the 2023 EC Communication on the Web4.0 and the European Digital Decade. It allows for differentiated implementation pathways across Member States, sectors, and user communities. The scenario's reasoning also reflects a key methodological principle: **narratives as strategic heuristics**. As discussed in Chapter 2, the final scenario configurations were validated for their strategic intelligibility, not for realism or internal consistency alone. In that sense, this scenario functions not as a target but as a **guiding configuration, a stimulating action-oriented track, and a lens for evaluating and anticipating risk, while generating common orientation across policymaking, research, and innovation domains.**

4.3 IMPLICATIONS FOR FORESIGHT AND TRANSITION TO ROADMAPPING

This meta-scenario also marks a transition in foresight, from exploration and sense-making to **strategy alignment and roadmap design**. It serves as a platform for Task 2.5, providing a **coherent, policy-sensitive frame** upon which recommendations, timelines, and institutional interventions can be mapped. For foresight, this scenario exemplifies the capacity of **narrative tools to mediate between complexity and choice**. It allows policymakers and stakeholders to rehearse the implications of different policy directions, stress-test emerging initiatives, and prioritise enabling actions without prematurely fixing endpoints. Maintaining conceptual openness and anchoring in real tensions ensures that foresight remains **agile, institutionally relevant, and future-compatible**.

4.4 META-SCENARIO NARRATIVE: CIVIC AND ECONOMICALLY PROMISING DIGITAL EUROPE 2030

By 2030, Europe will have become a global reference for how to align immersive technologies with democratic resilience. In the late 2020s, the EU consolidated a distinctive, pluralistic, human-centric, and foresight-informed approach to virtual worlds, combining its commitment to value-driven citizen protection while finding promising tracks to foster creative and practical, value-added developments, from an economic perspective. Rather than succumbing to imported platform models or abstract idealisations, the EU has opted for an adaptive configuration where open technological infrastructures coexist with clear normative anchors. In a virtual ecosystem defined neither by pervasive control nor laissez-faire, European virtual worlds operate as civic spaces which can coexist and even combine in multiple domains of activity with economically sound endeavours.

Social life, education, governance, and creativity unfold with equal legitimacy and industrial strengthening in these diverse virtual and XR-augmented places. Virtual Worlds have become an everyday layer of civic engagement across Europe. They are used for education, health services, collaborative governance, cultural production, creative and experimental prototyping and training capacity in numerous sectors and most cases with enriched social interaction, while not getting away from an always much needed institutional transparency, eventually empowering user agency, not as an additional virtue, but embedded at their core. Users encounter synthetic agents and co-created narratives not as opaque systems but as transparent counterparts integrated in accountable architectures.

People engage in memory-relevant co-constructed content, AI companions, and immersive public services within negotiated symbolic frameworks, guided not by the concerns stemming from international competition, corporate branding or sovereign control, but by cultural literacy and shared digital values. Users expect diversity in avatars or aesthetics, governance pathways, platform logics, and business models. As Europe's digital public sphere has expanded into virtual modalities, democratic practices have adapted accordingly to be more distributed, experimental, yet never unaccountable, and therefore always auditable and assessable. While not uniformly realised across all contexts, these developments are grounded in an ongoing effort to make virtual civic life inclusive and responsive, with ethics and values anchored in economically dynamic developments. Institutions have adopted a mix of traceable archives, participatory moderation, and hybrid civic spaces that blend physical presence with digital engagement, both for reliability and creativity, as needed, to foster increased trust in immersive systems.

Memory environments are no longer only tools of remembrance or entertainment; they are curated, meaningful participatory archives of shared, contested, and evolving histories. AI-generated agents and interfaces are deployed with periodically revised safeguards and human oversight supervision, but not at the cost of imagination and innovative endeavours. The boundaries between physical and virtual are increasingly porous, yet protected by traceability, accountability, and inclusive design systems, while still opening avenues for discovery and invention. The European virtual landscape is not singular but **ambidextrous**: it accommodates coexisting governance models, from structured regulatory frameworks for public services to sandboxed experimental spaces, for an extensive array of needs ranging from civic innovation and creative exploration to professional training and experimental prototyping of digital twins in many different sectors. This pluralistic and flexible approach allows Member States and local actors to test innovations in digital identity, immersive pedagogy, or emotionally intelligent AI, while maintaining shared civic accountability and all this, within the attention paid to their local capabilities and innovative specificities. The industrial sector, here to be taken in the broad sense, extending much beyond the manufacturing reference, has also found a new

foothold in this ecosystem. Virtual worlds are now used not only for internal simulations or customer engagement but also as full-fledged environments for collaborative product development, digital twin deployment, diverse monitoring capacities, and workforce training in controlled mixed reality environments or at a distance. Businesses can operate and learn to do so in hybrid contexts where market logic is balanced with social responsibility and ecological foresight. In this concrete perspective, the virtual can be envisaged no longer as a speculative add-on but as an integral layer of value creation, throughout the supply and value chains, especially in high-precision sectors such as energy, mobility, manufacturing, security, healthcare and urban development. This is not a utopia. Tensions and challenges will persist and require new solutions and even governance level adaptations, to optimally combine scale and openness, creativity and verification, affective and effective realism, and cognitive performance against sensorial overload.

Yet, these tensions are now subject to iterative governance quests, embedded in foresight-informed policymaking and their due evaluative capacity, and anchored in public–private–civic enabled cooperation. The private sector should find its value-added rationale in the virtual world development. The public sector, enhanced by human oversight and monitored AI support, will play a seminal, stimulating and experimental role, deploying exemplary test practices in its terms[56]. The European approach, regarding virtual worlds and the Web 4.0, is distinct thanks to its commitment to ambidexterity, which means preserving choice without fragmentation and innovating without abandoning collective human oversight. The virtual is no longer an elsewhere; it has become part of the European civic contract and builds upon the many European areas of excellence (as seen in section 3.2.8). Consequently, this meta-scenario embodies an evolving civic contract for the digital age, where sovereignty is enacted through infrastructure and continuous collective orientations, from local community interests to advanced science-industry collaborations and high-tech developments.

4.5 KEY SHAPING IMPACTS ON VIRTUAL WORLDS

4.5.1 A new typology, with distinct co-creation rationales and patterns

Virtual worlds are numerous and diverse. OPENVERSE Task 1.1 gave a first overview of this diversity by examining 75 virtual worlds from 22 countries across all continents with a certain level of detail and analytical depth. US-based, extremely popular, and gaming-oriented platforms showed a clear dominance. Still, European and Asian virtual worlds display many interesting features and points of growing originality. A first selection eliminated all non-GDPR-compliant virtual worlds and declining as well as controversial players of this arena to keep focus, for deeper analytical endeavour for 30 of them, bearing in mind a much stricter short listing for further co-creation endeavours (OPENVERSE Task 1.2 and 1.3, in particular). In this process, the question of types of virtual worlds emerged, along with ongoing discussions regarding taxonomies and the building of the OPENVERSE Observatory with WP leader Trust-IT. As shown in this Deliverable's figure 7, we have pragmatically distinguished our 30 virtual world inventory into five categories[57]: gaming, marketing and fashion, blockchain-related

[56] To see how the public sector could play a stimulating role, like for IoT, AI and blockchain innovation, cf. among other sources, Brizuela et al. (2024 : 15-17).

[57] There have been other typological discussions in OPENVERSE, essentially fitting the goal for which they were conceived, but which left us with a sense that we needed, for the foresight process, something closer to the reality of markets, business

capacities, socialising and what we call professional usages, most of this topological assignment being capable of overlapping with two or three other categories. As a result of all the discussions and comments that helped refine the topics under scrutiny, and then the proposed scenarios and their implications, we have come up with a new classification, not based on what virtual worlds were offering, but oriented towards the kind of markets and services they could preferentially address, with, of course, the acknowledgment of **a matrix-like type of overlap**. This revised classification goes as follows:

1. **Virtual worlds primarily geared towards entertainment**
   - 1.1. Virtual worlds with a gaming track record and still mainly game-minded
   - 1.2. Virtual worlds predominantly dedicated to socialising and community events
   - 1.3. Virtual worlds dedicated to art and culture, with some educational claims
2. **Virtual worlds with a professional orientation, meaning to be used by and useful for private and public organisations, which in turn involve end-users for professional reasons**
   - 2.1 Virtual worlds specialised in collaborative endeavours and services, including professional or marketing events
   - 2.2 Virtual worlds dedicated to developing, maintaining, and monitoring digital twins to manage specific ecosystems or high-demanding replicas, but involving collaborative processes
   - 2.3 Virtual worlds involved in mixed reality operations and simulated virtual reality needs for professional objectives, on-site or remote, and potentially also plural.

   The first part of these virtual worlds gains its value through the number of users, creators, virtual assets created, the monetised/monetisable value they represent[58] and, of course, the turnover of the companies operating them, as well as the partners they can build alliances with. The second part involves activities that are more difficult to evaluate; it is probably more sector- and even activity-dependent, and it has to consider not only the cost of licences but also the cost of implementation, calibration, customisation, and training.

Of course, the pertinence of this classification can be debated, and we see immediately how these categories may overlap, to the point that a 2D representation may prove insufficient, but we can nevertheless try:

models and the diversity co-creation practices: namely 1) a first "purpose" inventory proposed by POLIMI, i.e. an interesting snapshot view of seven categories of such purposes, but also with potential deepening discussions on general terms such as learning, working or service exploitation, and some missing dimensions such as simulation, for instance, and 2) a first hint, still likely to be enhanced over time, at the "affordances" of virtual worlds, linked with Task 2.1 led by Trust-IT, with at the moment 4 affordances, which just the same, can be nurtured to a more complete set of options covering the broad array of all that the virtual worlds of today propose, offer, allow, etc.

[58] These dimensions also suggest that the creativity, the originality and the talents involved matter.

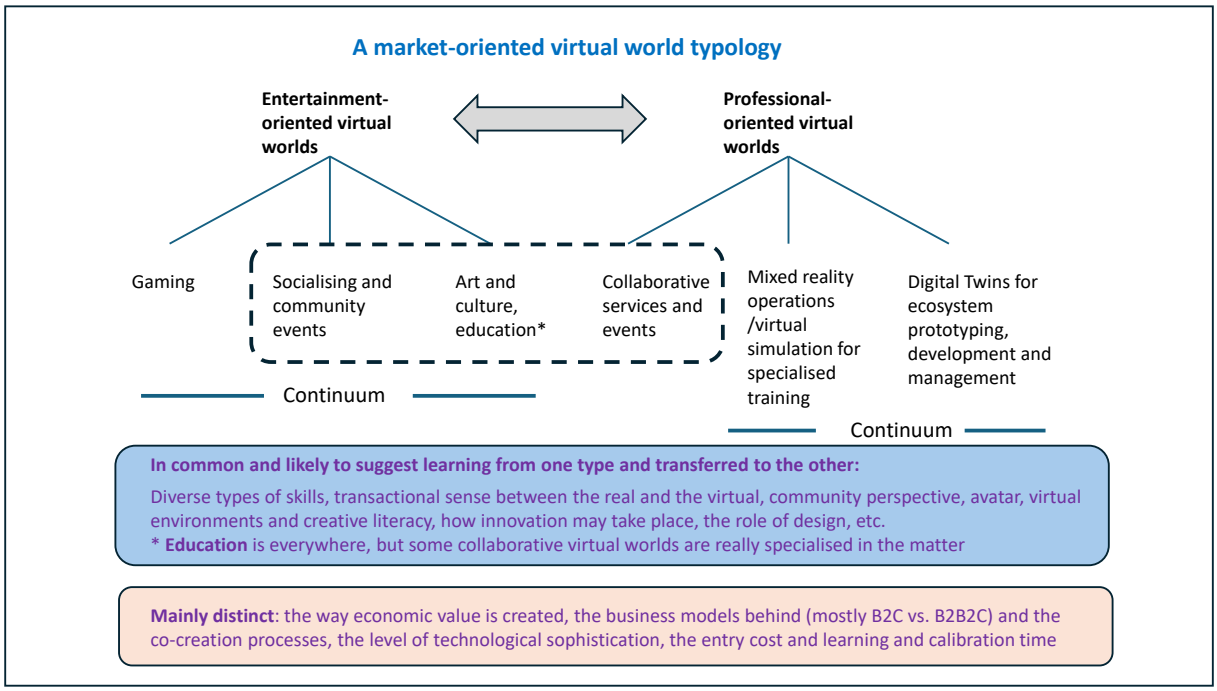

Fig. 8: A pragmatic and market-oriented typology proposal for virtual worlds

During this first approach, contrary to the Task 1.1 mapping retrieved for our Fig. 6, we did not consider the grade of integration of blockchain technologies, which would have created another level of intersection and complexity[59]. However, this factor, as suggested many times already, is a growing booster of virtual worlds, not only for NFTs and virtual asset monetisation, but for a large variety of other purposes, from immediate options such as smart contracts to growing (but still in the infancy) Decentralised Autonomous Organisations (DAO) or the use of practical Decentalised Finance (DeFi) in the virtual worlds.

4.5.2 SMES and start-ups, but also champions for collaborative creativity

In Task 2.3, we had the chance to examine and submit to a panel of experts our understanding of the following topic: “IPR challenges and barriers to the Single Digital Market for SMES and start-ups active in the Virtual Worlds and Web4.0 arena”. Not only have we been able to explore all the variations of the IPR issue, but we also parsed the numerous support initiatives and programmes that the EU has launched to support SMES and start-ups engaged in innovative digital activities. The advantages of the Single Digital market, much praised in particular by the Letta report, were balanced by examining barriers and hurdles that might negatively impact these key players of the virtual world arena. The JRC

[59] This is likely to be one of the next battlefield between regulatory needs and innovation support. In the matter, in the EU, the situation is as follows. The Markets in Crypto-Assets Regulation (MiCAR) was introduced as part of the EU’s Fintech Action Plan, it came into force on 30 June 2023. The rules on stablecoins have taken effect, with full implementation by 30 December 2024. MiCAR aims to create financial regulations suited for the digital age and innovative technologies, emphasizing the EU’s commitment to fostering the adoption of Distributed Ledger Technology (DLT) in finance. MiCAR recognizing that crypto-assets fall somehow outside the scope of existing EU financial regulations, the need to supplement anti-money laundering rules and thereupon enhance the legal framework to foster crypto-asset market growth in the EU, while addressing the risks related to market integrity, financial crime, and lack of consumer protection.

study already mentioned (De Hont et al. 2023) inventoried 27'000 activities involved in that market. It is a considerable number and likely to expand (with 18'500 active entities in the EU perimeter). In particular, as it was raised more than once in our workshops, from that observation and also as it seems to sprout in the US, there is a trend through which users can become creators and designers of virtual content on their own terms, boosting this capacity. However, as time passed and the signals from the urgency to think of the Draghi report message and industrial and economic sovereignty, the need to connect this much-needed bottom-up concern with the other need, i.e. to promote European champions, especially of high economic yield, became clear and, therefore, had to be addressed. In our fourth workshop, we invited a representative of Siemens, who could explain how they are engaged in the virtual world development, and we could foresee some of the tracks that we could suggest, connecting the SME level of virtual world engagement with the involvement of these major players (the ongoing partnership with such leaders as Siemens) being a beginning., not and end it itself).

Looking at it with more attention, we see that there are more champions already active in the virtual world arena than we could think of at first glance, and in addition, they are active in several crucial fields. It is not the place here to initiate an inventory of the kind (more the role of the Observatory). Still, it is true that beside the strong impulse provide by Siemens in the various domains in which that company is developing technological services of the highest level, there are other industrial players e.g. Dassault), and also service players (e.g. SAP) as well as many already providing inspiring use cases in the healthcare sector and security services, while the urban virtual worlds are presenting an extensive array of valuable accomplishments with the support of partial or even sometimes entirely innovative XR and virtual-world applications. Apart from these major players, specialised XR and virtual worlds developers are helping them through diverse innovative applications, devices or services. The true journey to consider is the synergetic combination of players of different sizes, statuses, regions and sectoral track records.

In this seminal context, the educational field is also worth mentioning, as it is indeed flourishing, through the involvement of both private and public companies. As a result, the SME focus has to be connected with the championing mindset, which the EU has to support and pay attention to. In the present international context, these are the precious relays of our development; essentially, with which European values are compatible. Collaboration between these actors must be encouraged, developed and steadily nurtured. In some domains (healthcare, mobility, urban twins, security, tourism), there may be interesting private-public partnerships to conceive or already existing, but then to expand, positively supporting the learning curve of that small and big player connection.

4.5.3 For XR and VW makers: a designer market to foster in several economic sectors

XR and virtual makers, designers, expert users and professional agencies capable of identifying valuable and quality players in that ongoing development, with or without AI support, are converging towards a new kind of distributed creativity, the design role being pivotal in that ecosystem in which technology, imagination and business objectives interplay. They seem to be a bit in advance in the US in that continuum between users and the diverse private companies involved in developing virtual worlds, virtual devices and assets, but not to the point that this should be considered as a gap, much to the contrary, a stimulating challenge. The EU areas of excellence[60] in the industry, in luxury, in science and in some high-demanding sectors like healthcare, manufacturing, security, sport, tourism and citiverses, as much as the entertainment strand of the virtual world arena, can envisage great

[60] See a first inventory of these promising options in section 3.2.8.

ambitions, mobilising wherever needed the multiplicity of small players who fit the JRC figures (27'000 activities engaged in virtual creation[61] by some 330'000 entities worldwide, but at least 18'500 in the EU perimeter). This shows the level of intensity of virtual world development. However, in the EU context, the makers and the communities of different regions involved in this field may be short of financing support (we will come back to this) and may therefore encounter difficulties connecting with the Single Digital Market. In the current situation, the policy support should play a minimal role with the above-mentioned facets of EU excellence (the Single Digital market is "more than just a market" as the Letta report expressed it, i.e., a stimulating area of opportunities). XR is a world of specialised investment, while virtual world platforms allow diverse kinds of social interactions, which may strengthen communities of users and developers. As all have been educated in the value-sensitive environment which our scenario 2 tries to preserve and which, even in a flexible form, should be maintained and asserted, we can indeed consider that in the medium term, this will start to pay, and in the short term, we can bet on this multiple source of stimulation and support that the EU, the MS encouragement programmes but also public private partnerships can foster. The five years that begin now until the 2030 time horizon should be dedicated to capturing all possible waves and networked forces moving in that direction. In the middle, between end users and developers, the EU should also value the various types of design-minded institutional and economic actors, including those in the diverse segments of the creative industry.

4.5.4 The education and skill acquisition threshold for Virtual Worlds and the Web4.0

In that context, the education arena, in its diverse modalities (schools), also includes professional training, coaching and mentoring, and team building, with a variety of participatory processes and community initiatives as civic types of schooling. Local groups may experiment and learn about the environment, how to protect their health and their security, and interact with local policy-makers to make critical choices in construction, mobility or waste management, all domains for which, as already suggested, XR and virtual worlds can provide a considerable number of services. Taking this broad perspective, education can be envisioned not merely as a distinct sector of activity, but as one that stands to benefit from open and lifelong learning practices. This virtual competence shift has the potential to enrich individuals, groups, institutions, governments, and private enterprises alike, uniting a diverse array of stakeholders and fostering the creation of new forms of functional experience. The stake is high, as there is a specialised brain shortage in all European countries[62]. It is not so much an update in digital literacy that will matter, but a broader and deeper cultural acquisition of how to use and contribute to developing digital solutions, XR and virtual worlds being strong candidates for that, now almost always with AI in support, to acquire skills and share them while preserving a baseline discerning capability.

All the virtual worlds we have categorised in this section can help build the blocks of that broad educational programme, with always the capacity needed to accomplish several things at the same time: learning and assessing, using and co-creating, personal and collective engagement, civic and job-oriented action, short and longer term, etc. This skill issue is also linked to the financing question. One of the participants at the 4th workshop mentioned several examples of missed opportunities for

[61] See for that, the JRC report by De Hont et al. (2023: 71).

[62] This is known as the STEM deficit, in which the domains of Science, Technology, Engineering and Mathematics are not provided, thanks to the sole national educational effort, the level of manpower needed for an effective digital development. Worth mentioning, linked to OPENVERSE, this problem has been emphasised as key emergency by the Lisbon Council (2025).

Europe, of developments started in the EU, but then bought out to develop their market-maturing stage in the US[63]. This multi-ambidexterity is at the core of how the virtual world and the Web4.0 will become part of our toolset.[64]

4.5.5 "Open", "human-centric" and "sustainable innovation" in Virtual worlds

From then on, the goal has been set since the beginning: to be capable of proposing and contributing to developing open and human-centric virtual worlds. Or, rather, developing this capability either through one specific generic yet multi-usage platform (but then most likely through the strengthening of an existing EU application) or within all EU anchored virtual worlds, or in the worst case, with those international platforms allowing for narrowing down the gap with EU values. In this constructive process, "open" is not only restricted to open source (how valuable this dimension may be), as we explained in OPENVERSE Task 2.3, workshop 3, it is about everything which can open, expand, diversify and motivate the options that makers and designers of virtual worlds solutions may encounter and will have to strive for. Beyond the existing references of formal IPR, for makers to go through should they bet on protection rather than speed and co-creation within specific contractual agreements, or for software developers who are automatically protected, there is an open innovation space to explore, positively colonise and partner in. This is also a competence to be acquired, just as learning the means for accessing official EU or MS IPR (see for that OPENVERSE Task 3.5).

If "open" is the "how" to undertake, "human-centric" is the "what": virtual worlds developments, creation of virtual assets, designs, new communities, art and culture events promoted through these channels can be said "human-centric" either because they are developed thanks to the engagement and co-creative participation of users and designers, or because the activities that are generated have a human value, for their immediate impact or as long as they foster positive changes in crucial societal challenges (with social, health or environment dimensions involved). In that set of requirements for co-creation of virtual worlds, within our foresight space and its axes, the sustainable innovation claim is the most ambiguous, almost an oxymoron, but also a challenge per se, namely: how to translate the leitmotif of innovating into something sustainable, first businesswise, which is already not so easy, but also, if possible, should one assume the claim, with a high endorsement of UN SDGs. Almost mission impossible, as if it had to be one or the other, but not one AND the other.

This is precisely where the ambidextrous assumption makes the difference: to promote and engage in virtual world co-creation which complies with ethics and regulatory requirements encompassing the EU values regarding the digital, green objectives and inclusivity and social cohesion clause, meaning striving for the success, consistency and durability of real transformational activities. To make sure we do not miss any opportunity to "open" options, let's also stress that the development of distributed ledger technologies and in particular Decentralised Autonomous Organisations, can also foster different types of geographical, sectoral and community-driven interests, conveying an essential open organisation and open innovation spirit in their own terms. Decentralisation, in this perspective, involves real possibilities to bypass dominant players' influence, including getting access to other forms of financing tracks (DeFi). It will take time until this type of configuration is fully adopted. Still, it belongs

[63] This means that the new financing scheme (see next section) should also be able to detect and support potential champions, which will not be easy unless the EU innovation financing market grows and learns.

[64] A perfect document to emphasise how the educational perspective can be boosted by XR and virtual world developments, can be found in the seminal report to the JRC/EUR 31652, of Tuomi et al. (2023).

to the possibility of SMES allying with others to build and disseminate new capacities in the virtual world arena, much beyond the monetization of virtual assets[65].

4.5.6 Financing XR and VW innovation in international competition with the US and Asia

Finance scarcity has been cited more than once, even in surveys on the question of why the adoption of digital innovation or the development of new applications and services seems to be so hard. We have no answer to that, but in a time in which the EU is in quest of an increased technological independence, and in which defence issues appear to be critically urgent[66], a type of financial institutions like a EU Nasdaq, capable of maintaining in Europe and dedicated to promoting the European economy and goals for all the savings and the pension funds, instead of seeing them going to more attractive areas, seems a legitimate objective. This idea is also aligned with the perception, in a world of uncertainties, that European stability may represent a decisive attractor of its own, and will soon be at the centre of a responsible strategy[67]. Let's acknowledge, however, that the EU has been aware of this problem for some time and that the Commission has announced the following, precisely on the objective of exploiting the savings market:

- "a **European Savings and Investments Union** to create new savings and investment products, provide incentives for risk capital, and ensure investments flow seamlessly across the EU" ("a refocused EU budget will streamline access to EU funds in line with EU priorities")[68],

- a **Competitiveness Fund**, which will replace multiple existing EU financial instruments with similar objectives, providing financial support to implement actions under the Competitiveness Coordination Tool (also in the Digital Compass, 2025 c).

New alliances, including in the virtual world arena (some exist already, of course, like the US editor EPIC Games), but maybe with innovative specialities, of significant community interests for the EU needs, will also make their way forward. We have seen that beside the popular gaming platforms which US companies have developed, there are also more professional virtual worlds to compare with in the US, in Europe and in Asia, and even more so within the European areas of excellence we have evoked and, of course, paying attention to and supporting the already burgeoning European virtual worlds we have identified (and some others who have emerged since then).[69]

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[65] To get an idea of what can become valuable tomorrow, concerning virtual worlds of a professional kind: "European SME Expertise in 5G and Beyond 2024" Brochure Now Available – NetworldEurope ETP and also, for how SMEs can be valued: sme-wg-sns-position-paper-final.pdf

[66] It is worth stressing here that the security and defence sector constitutes a very promising area of development for EU XR and virtual world players.

[67] In the current context of uncertainty, with the return of protectionism and threats to multilateral institutions, 2030 seems to be a reasonable deadline for such an ambitious promotional threshold.

[68] Excerpt from the Digital Compass (EU commission, 2025 c).

[69] So far, we have considered that the virtual worlds made, enhanced or co-designed with European resources would naturally serve primarily the European market. Still, even if the change of habits is not established yet, nothing prevents European players from distributing and licencing their products or services to the extra-European countries, primarily counting on the fact that in Asia (according to Durand-Hayes et al. (2023), apart from the most innovative countries (China, Japan and South Korea) the fastest growing consumer markets are Vietnam and Indonesia.

In this large-scale perspective, it is worth mentioning that some developments and programmes, such as the ones fostered by the Strategic Research and Innovation Agenda (SRIA) 2024-2030, SMEs are considered as relevant actors of the partnerships with the companies shaping the key verticals that are expected to boost European competitiveness[70]. Let's also remind here that the EOSC Strategic Research and Innovation Agenda is to define the general framework for future research, development and innovation activities concerning the European Open Science Cloud, and therefore quite in line with the suggestions we made for the meta-scenario on partnerships in key European areas of excellence. One of the best views on this multi-objective ambition of the OPENVERSE project was proposed by our colleague Luke Porwol for Task 5.3, during the internal workshop of Jan. 21, 2025, proposing a series of synergetic tracks to build open and human-centric virtual worlds:

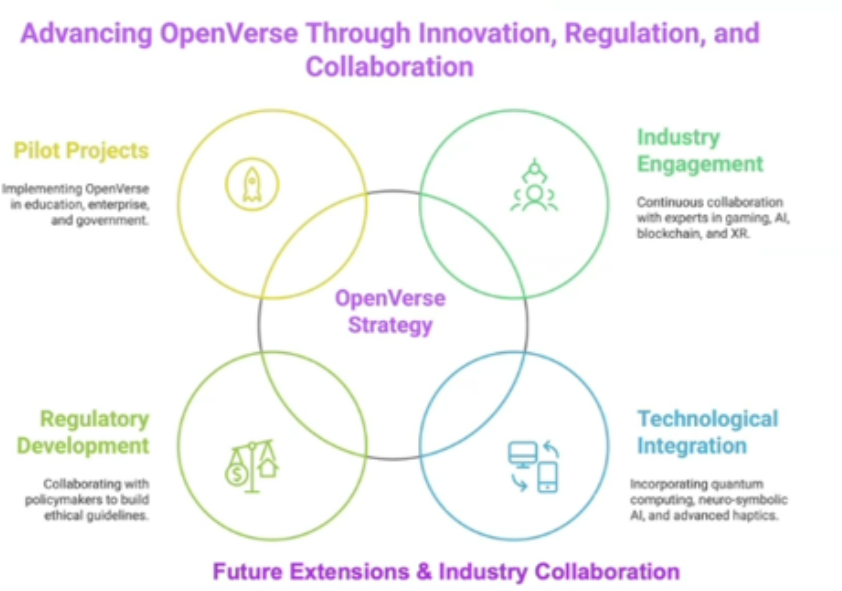

Fig. 9: From OPENVERSE Task 5.1, an overview of how the project components should converge and build our open, human-centric and sustainable EU virtual worlds

4.6 TAKEAWAYS FROM THE META-SCENARIO

The meta-scenario presented in this chapter and supported by a series of key reflections anchored in the need to support in the best manner the deployment of virtual worlds at European level, affirms that for its digital future, the EU does not need to choose between openness and protection, centralisation and experimentation, or innovation and ethics. Instead, it demonstrates how a **strategically aligned and value-anchored configuration** can create space for plural virtual futures, without abandoning coherence and safety concerns. It also highlights the importance of **institutional flexibility, civic engagement, learning infrastructures, and economic development needs** as conditions for navigating complexity and long-term uncertainty. Most of all, it offers a platform from which to begin mapping actionable policy pathways, anchored in possibility but driven by purpose.

70 sme-wg-sns-position-paper-final.pdf

5 CONCLUSION

This foresight exercise has sought to anticipate and map the trajectories of virtual worlds and Web 4.0 technologies within a European context, balancing near-term actionability with long-term strategic resilience. Through the dual time horizons of 2030 and 2040, we explored both the immediate imperatives of innovation policy and the deeper uncertainties that will shape future societies. The scenario-building process, key debates, and preferential meta-scenario have together framed a vision that is ambitious yet grounded in critical reflection on emerging technologies, social dynamics, and environmental constraints.

The virtual worlds of tomorrow will not emerge solely from technological evolution but from the conscious choices made today—by policymakers, entrepreneurs, researchers, and citizens alike. Building Europe's ambidextrous horizon means fostering open, human-centric, sustainable innovation while navigating systemic risks and reinforcing digital sovereignty. It also means recognizing the cultural and generational shifts, many seeded by the gaming industry and immersive technologies, that are already reshaping expectations around identity, governance, and collaboration in virtual spaces.

In moving from foresight to roadmap development, Europe has a historic opportunity to influence the global evolution of virtual worlds, setting standards that prioritize creativity, diversity, trust, and societal wellbeing. The pathways outlined here are not prescriptions but invitations—to innovate with responsibility, to anticipate with imagination, and to lead with vision.

Upon the views, comments, clues and knowledge insights produced within the foresight process reported upon in this Deliverable and bearing in mind what it is meant to be useful for, we can come up with a quite challenging agenda for the immediate future. To summarise these next steps, we have in fact two main tasks ahead of us.

1. To build on this foresight work to elaborate a roadmap and policy recommendations. This OPENVERSE **Task 2.5**, starting immediately, and connected to the Policy Brief assignment of WP7. This will lead to the setting up of two workshops, one in 2025 and one near the end of the project, in 2026, with policy-makers as the main stakeholders.

2. This Deliverable has been elaborated thanks to the participation of experts from diverse fields, but we must stress that among them, there were several members of the OPENVERSE Consortium, themselves involved in the advancement of Work Packages and tasks, and that we, in turn, have participated in diverse other tasks. However, besides this exchange of ideas and participatory practices, Deliverable 2.3 has the mission of contributing directly (with some specific tasks) or indirectly (with others) to the advancement of OPENVERSE in general.

Here below is the table of all these ongoing or remaining OPENVERSE tasks. With several of them, we have already engaged in regular and mutually profitable exchanges, while with others, it will be time, from now on, with the results of this deliverable, to connect and make sure we can be useful, as needed and in the most timely form.

Table 1: The diverse ongoing/ remaining OPENVERSE tasks this Deliverable may nurture

Tasks	Assignment, leader and target time
T1.3	Elaboration and implementation of co-creation methodologies (Lead: PO), M12-26
T2.1	Technology watch and taxonomy (Lead: Trust-IT), M1-36
T2.2	Marketplace of opportunities (Lead: Trust-IT), M1-36
T2.5	Roadmapping and Policy Recommendations (Lead: IF), M12-36
T3.2	Exploratory study on existing metaverse environments (Lead: LC), M13-24
T3.3	Demonstration case on Metaverse-Enabled Robotics: Developing Industry-Focused Use Cases for Enhanced Collaboration (Lead: VUB), M13-24
T3.4	Ethical and legal requirements for a European Open and Human Centric virtual world (Lead: INS), M5-24
T3.5	IPR and Governance Models for an Open and Human Centric Metaverse (Lead: INS), M5-24)
T5.1	Technological synergies (Lead: INS), M6-36
T5.3	Collaborate and build synergies with other existing related EU initiatives (Lead: BDVA), M1-36
T6.1	Input to industry standards (Lead: BDVA), M14-36
T6.3	Development of the project observatory (Lead: Trust-IT), M18-36

The collaboration on Policy Briefs associated with Work Package 7 is worth mentioning within the list.

With the reminder on Task 2.4 assignment and its expected outcome[71], we temporarily close the loop, hoping that this knowledge input will have contributed, at its level and in its particular timeframe in the OPENVERSE project, to advance us towards open and co-created virtual worlds for Europe.

[71] The Consortium and all the WPs and task leaders concerned will have access to this document.

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ANNEX I: THE SCENARIO-BUILDING PROCESS

1. Decisive factors shaping the foresight space

This Annex I synthesises the principal drivers and tensions identified during the foresight workshops that collectively shaped the scenario space for virtual worlds and Web 4.0. These factors were partly extracted from pre-existing sources OPENVERSE activities, but were also mainly surfaced, discussed, and progressively refined through participatory reflection and expert deliberation. Rather than treating trends as static or external, the foresight process approached them as dynamic and co-constructed. Their value lay not only in what they revealed individually but in how they interacted (often synergistically or tensely) with one another. These interactions laid the conceptual groundwork for developing structured and contrastive scenarios that follow later in the deliverable.

Throughout a series of structured workshops, a number of key influential factors, to a great extent having emerged from preceding OPENVERSE activities, but also from the interactive work deployed during the workshops, were interrogated and debated by the various participating stakeholders, including policymakers, scholars, technologists, and civil society actors. Rather than serving as passive inputs, they became active components in constructing a flexible, multidimensional foresight space. Their ongoing negotiation and refinement enabled diverging yet coherent scenario narratives, grounded in expertise and deliberative judgment.

Technology was treated not as a deterministic input but as a socio-technical configuration, emerging from investment patterns, institutional framing, and user practices. While several technologies were discussed, some were seen as having particular structuring power over the development of virtual worlds.

Artificial Intelligence (AI) is featured prominently, especially in its evolving role in shaping user experience, curating content, influencing emotional engagement, and configuring memory environments. Views differed on whether AI would serve as a tool for human-centred empowerment or might become a source of opacity and epistemic risk. Its implications for authorship, identity, and narrative control were recurring themes.

Extended Reality (XR) technologies were also considered central, but their diffusion raised critical questions. Experts discussed whether immersive access would remain an optional layer or become an infrastructural expectation. Barriers to adoption, including hardware limitations and socio-cultural inertia, were not viewed as merely technical challenges, but as indicators of deeper tensions between technological ambition and lived reality. This XR technology domain, often seminal and more than once taken as an equivalent to virtual worlds, an ambiguous status which remained perceptible in the experts' comments all the way through the foresight process, also involved discussions on the standardisation gaps and key ethical and societal challenges. Generally speaking, the methodology deployed always tried to balance technological factors with non technological ones, XR technologies being often a means to tackle in depth some of the influential factors encompassed in virtual worlds.

Further technologies, including **blockchain, digital twins, IoT, and neural interfaces**, were debated for their enabling potential in decentralisation, transparency, and interoperability. However, participants frequently questioned whether the rhetoric of decentralisation corresponded with the reality of persistent centralised control by dominant platform actors, highlighting a mismatch between aspiration and implementation in the evolving architecture of Web 4.0.

A recurring theme was the interplay between innovation dynamics and normative regulation, particularly in a European context. Participants acknowledged Europe's proactive stance in digital governance, through frameworks such as GDPR, the AI Act, and DSA, but questioned whether these initiatives could scale alongside rapidly evolving technologies. The potential trade-offs between normative ambition and market agility were debated. Some advocated for modular and adaptive governance mechanisms, including sandbox regulation and co-creation processes with industry and civil society actors. Others stressed the need for more substantial investment in critical technological capabilities, including AI and cybersecurity, to ensure that infrastructural dependency does not undermine values-based governance. This dialectic was understood not as a binary opposition but as a generative tension. Regulatory leadership and innovation need not be mutually exclusive, but their coordination demands strategic foresight, institutional flexibility, and alignment with areas of existing European strength.

All these factors and potential influences likely to shape a virtual worlds were treated during the interactive sessions of the 4 foresight workshops.

2. Iterative Construction: From Foresight Questions to Co-Created Narratives

The scenario-building process unfolded as a structured yet adaptive sequence of workshops, each contributing a conceptual and methodological layer to the final outputs. Rather than introducing predefined narratives, the process invited experts to co-articulate, critique, and evolve the scenario space over time. Each session served as both a standalone exploration and a cumulative building block, progressively enhancing the coherence and depth of the emerging scenarios.

2.1 Establishing the Dimensions: Workshop I (January 19th, 2025)

The first workshop focused on identifying the structuring tensions and conceptual axes for the scenario design step. Through breakout groups and the plenary synthesis, participants formulated two key dimensions:

- The **degree of openness** in technological and governance architectures;
- The **orientation of innovation**, ranging from market-driven to public value-centred.

Rather than proposing these dimensions in advance, the process allowed them to emerge from clustering exercises and deliberation. These two axes were subsequently visualised as a two-dimensional matrix, a conceptual field into which various futures could be positioned.

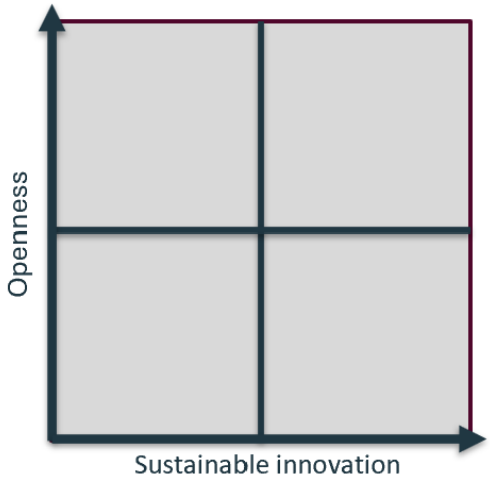


Fig. 10 - The original two-dimensional matrix established to provide the frame for scenario design

This framing laid the groundwork for more detailed thematic exploration and narrative experimentation in the following workshops. The purpose of such a topology exercise is to help threshold the scenarios.

2.2 Scenario Seeds and Thematic Threads: Workshop II (February 6th, 2025)

Building on the initial dimensions, Workshop II deepened the scenario space by exploring key uncertainties, enablers, and socio-technical tensions. Participants engaged in thematic breakout sessions and used interactive MIRO boards to identify and cluster concepts. The aim was not to define

scenarios outright, but to formulate structured “proto-scenarios”, narrative seeds grounded in earlier typologies and ongoing foresight debates.

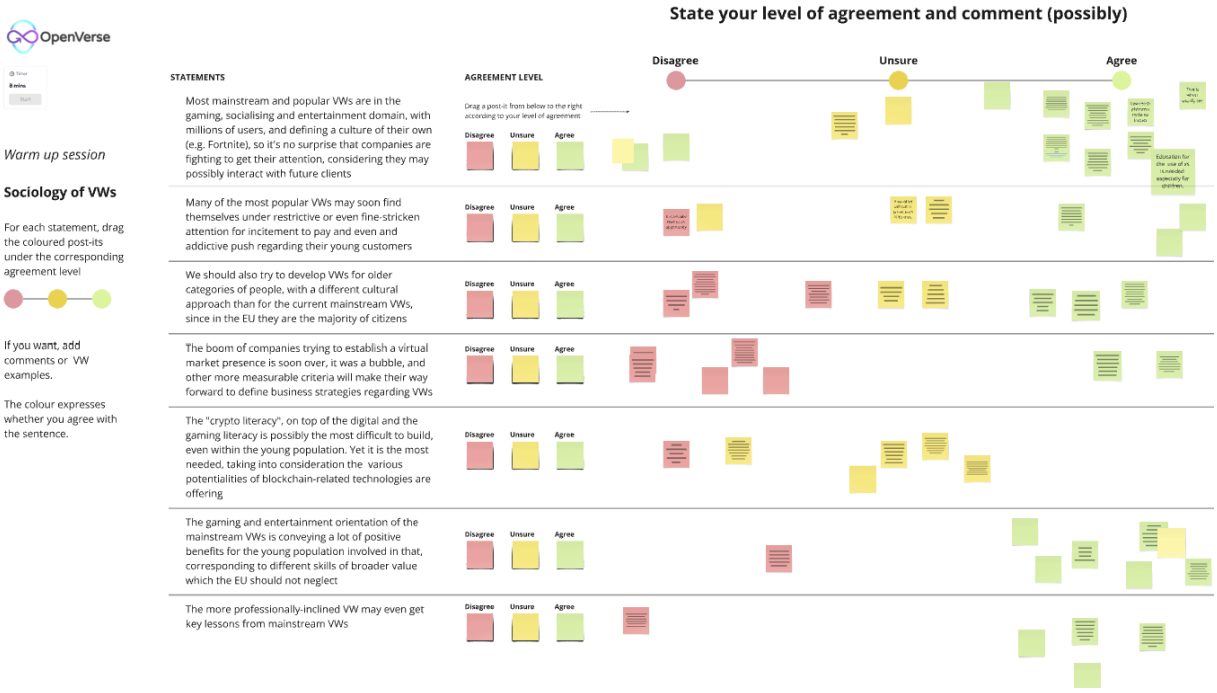


Fig. 11 - One of the original MIRO boards developed for Session II of the series

Key themes included decentralisation versus centralisation, AI in knowledge and emotional curation, and the social implications of immersive technologies. A participatory open-question round encouraged reflection on policy dilemmas and social consequences, enriching the narrative material while anchoring it in plausible institutional and technological trajectories.

2.3 Topology and Cross-Cutting Uncertainties

In Workshops III and IV, participants used topological exercises to map the evolving scenarios spatially. Using interactive visualisation tools, they located each scenario within a foresight landscape shaped by dimensions such as openness, governance ambition, technological sovereignty, and cultural coherence. Rather than forcing scenarios into fixed quadrants, this approach revealed areas of overlap, tension, and convergence. It also helped clarify the multi-dimensional nature of key uncertainties.

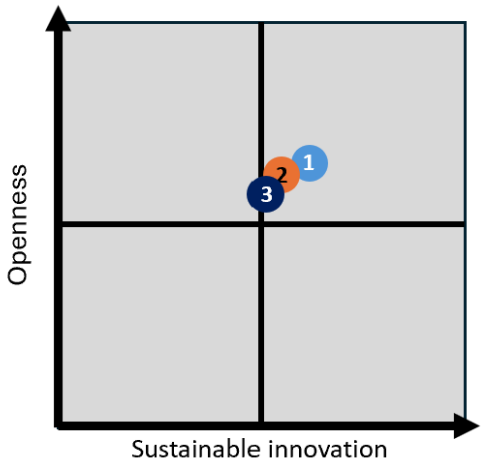


Fig. 12 - The first topological positioning of the three scenarios. Explanation: Number 1 represents "Developing Our Ambidexterity", while number 2 represents "Values Will Eventually Make a Difference, and number 3 represents "More of the Same"

Five transversal tensions were especially influential:

- **Governance vs. Participation**
- **Human Agency vs. Algorithmic Influence**
- **Innovation vs. Equity**
- **Interoperability vs. Fragmentation**
- **Narrative Authority vs. Speculative Pluralism**

These tensions were not merely theoretical; they shaped the narrative evolution of each scenario and highlighted possible zones of conflict or innovation. The mapping underscored the complex landscape within which strategic futures must be imagined and the value of maintaining flexibility in scenario articulation.

2.4 Narrative Co-Creation: Workshop III (March 18th, 2025)

Workshop III introduced fictional vignettes, short "tales" set in the year 2040, as narrative provocations designed to stimulate critique and elaboration. These were not finalised scenarios but imaginative anchors intended to surface blind spots and test narrative coherence. Participants reviewed and repositioned these tales using Mentimeter exercises, aligning them with previously established foresight axes. This helped refine their internal logic and strategic distinctiveness while surfacing normative tensions and institutional assumptions. One story, "The Architect's Dilemma", later evolved into the scenario "Developing Our Ambidexterity". It captured a more nuanced, ambivalent governance and innovation model that moved beyond binary positions and highlighted negotiated complexity. Participants' feedback helped this scenario mature into the set's most balanced and flexible narrative.

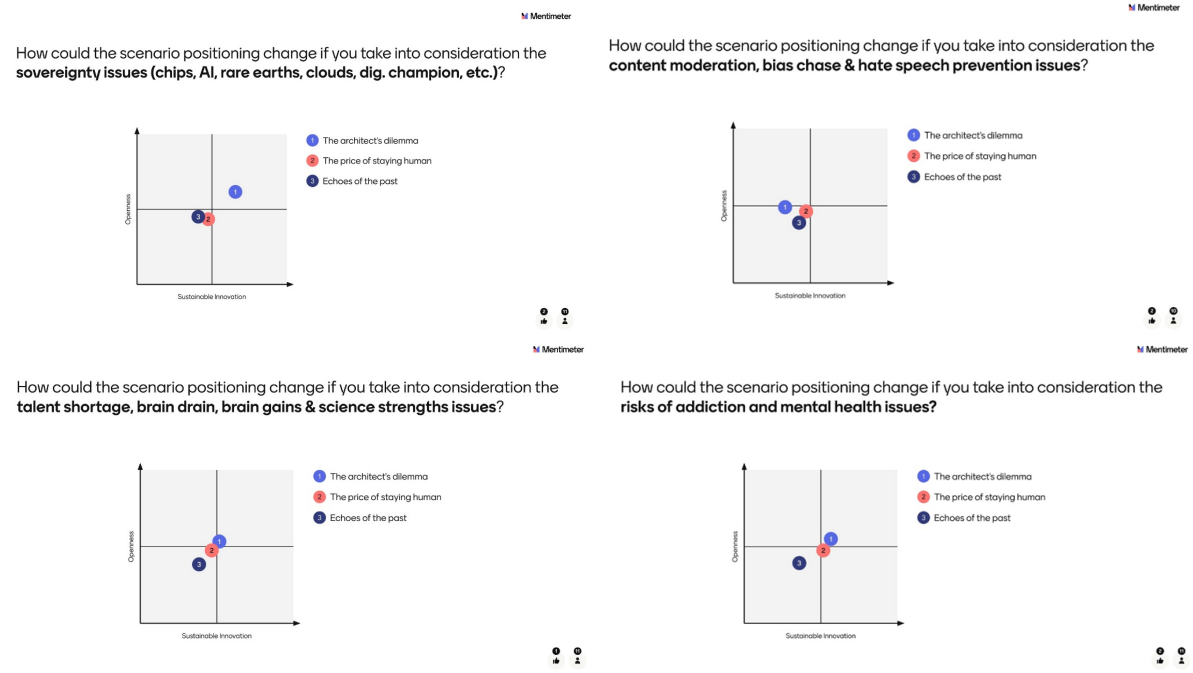


Fig. 13 – Results from all four topological questions delivered in Workshop III

2.5 Consolidation and Validation: Workshop IV (April 8th, 2025)

The final workshop validated, critiqued, and consolidated the three scenarios in their near-final forms. Titles and narrative trajectories had stabilised mainly, but participant input focused on coherence, time-horizon calibration (2030 vs. 2040), and responsiveness to emerging risks. Another topological exercise helped assess whether the scenarios occupied sufficiently distinct and plausible zones of the foresight space. This was not a ranking activity but a test of strategic completeness and narrative utility. Scenarios were adjusted in response to how participants evaluated their fit against critical uncertainties, such as AI saturation, content moderation challenges, and digital sovereignty.

The question was introduced by a short quote from the Draghi report [*"Europe largely missed out on the digital revolution led by the internet and the productivity gains it brought: in fact, the productivity gap between the EU and the US is largely explained by the tech sector" (M. Draghi)*], and went like this: **The Draghi and Letta reports (both issued in 2024) highlighted an urgent need to engage in the reindustrialisation of the EU. Given the three scenarios presented in this work, how much & how specifically will these two "strategic calls" influence the future of virtual worlds?**

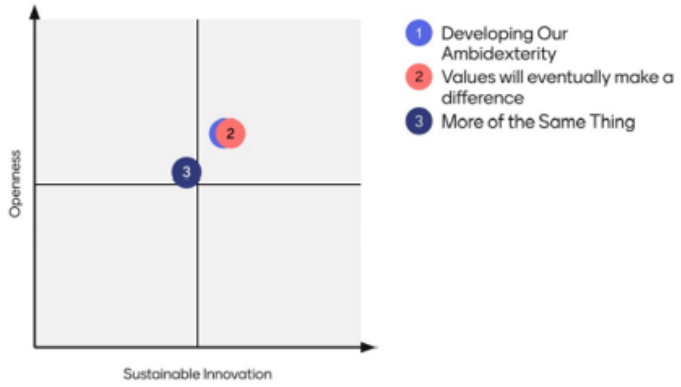


Fig. 14 - The only topological question included in Workshop IV's interactive session

The session concluded with reflections on the scenarios' potential relevance for European digital policy and governance. Participants discussed how each scenario might highlight current blind spots and inform future anticipatory strategies. These insights contributed directly to the articulation of policy-oriented outputs and will be further integrated into the conclusions of the deliverable.

3 The Final Scenario Set and Its Strategic Validation

The scenario-building process culminated in three distinct but interrelated narratives, each reflecting a unique configuration of technological trajectories, governance strategies, and socio-cultural orientations within the evolving domain of virtual worlds. These scenarios are not forecasts but foresight artefacts: structured heuristic tools designed to explore plausible futures and test the resilience of strategic assumptions. Each scenario emerged through iterative feedback loops, integrating expert critiques, topological mapping, and narrative co-creation. Their design sought not consensus but contrast, highlighting different strategic logics and tensions to support anticipatory thinking. The three scenarios (*Developing Our Ambidexterity*, *Values Will Eventually Make a Difference*, and *More of the Same*) offer distinct vantage points on how Europe might navigate the virtual domain by 2030 and provide a foundation for further exploration of long-term trajectories.

3.1 Scenario I – Developing Our Ambidexterity (The Architect's Dilemma)

This scenario envisions a pluralistic European virtual ecosystem shaped by iterative governance, decentralised innovation, and adaptive institutional design. Rather than prescribing uniform regulatory frameworks, public actors facilitate sandboxed environments for experimentation in areas such as virtual education, cultural heritage, and collaborative design. Governance evolves through co-creation, drawing input from users, developers, researchers, and civic bodies. Symbolic and emotional dimensions of immersive experience are foregrounded. Rather than privileging strict factual accuracy, platforms support creative reinterpretation and speculative storytelling, particularly in memory-rich environments. Synthetic memory is recognised not merely as a technological artefact, but as a cultural practice requiring transparency, accountability, and participatory curation. Institutional models vary across Member States. Some prioritise public broadcasting as a digital heritage custodian; others favour cooperative governance mediated through smart contracts and ethical AI systems. Interoperability is pursued through technical standards, cultural negotiation, and mutual recognition. However, challenges remain. Competing value systems and institutional asymmetries lead to

contested grey zones. Disinformation and manipulative storytelling persist in some corners of the ecosystem. Governance reflexivity is essential, but remains vulnerable to geopolitical shocks and institutional overload.

Strategic Implications

This scenario models a reflexive, adaptive governance architecture that balances creativity with accountability. It underscores the importance of institutional agility and pluralism and invites policymakers to support experimental governance ecosystems without abandoning normative commitments.

3.2 Scenario II – Values Will Eventually Make a Difference (The Price of Remaining Human)

This scenario projects a Europe that consolidates its leadership in normative digital governance by implementing a comprehensive rights-based framework for virtual worlds. Triggered by growing concerns over AI misuse, platform opacity, and psychological harms, the EU introduces robust regulatory instruments covering synthetic content, emotional AI, and memory governance. Member States align national strategies with EU-level directives. Public virtual environments are treated as critical infrastructure, governed by transparency-by-design protocols and citizen oversight. Innovation continues but within narrowly defined ethical boundaries. European actors focus on developing trust-enhancing technologies such as verifiable provenance systems, hybrid moderation mechanisms, and participatory design platforms. While this model offers ethical clarity and institutional stability, it also faces constraints. Regulatory overhead slows innovation, and European platforms struggle to scale globally. An unregulated parallel ecosystem emerges, offering emotionally unrestricted services beyond EU jurisdiction. The tension between safeguarding autonomy and curbing excess leads to growing debate about the limits of normative control.

Strategic Implications

This scenario illustrates the opportunities and limits of strong normative governance. It highlights the risks of regulatory overreach and dependency on extraterritorial systems, while affirming the value of ethical coherence, institutional legitimacy, and user trust.

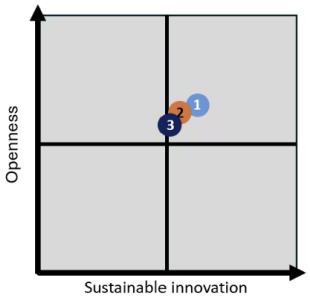
3.3 Scenario III – More of the Same (Echoes of the Past)

This scenario extrapolates current trends, depicting a Europe where global commercial platforms dominate immersive environments. Virtual experiences become seamlessly embedded in daily life, mediated by AI systems that personalise content, curate memory, and manage affective engagement. Users increasingly rely on synthetic environments for comfort, continuity, and connection. Customisation reaches new levels of emotional fidelity: digital memorials, nostalgia loops, and AI companions cater to personal and cultural memory. These services are widely adopted, especially among ageing populations and diaspora communities. However, concerns about dependency, psychological impact, and epistemic manipulation intensify. Regulatory frameworks remain fragmented and reactive. EU-level efforts to promote open-source alternatives persist but struggle to scale. Civil society calls for memory rights, and synthetic content disclaimers are marginalised. Dominant platforms continue to shape cultural perception, historical understanding, and emotional validation.

Strategic Implications

This scenario captures the risks of regulatory inertia and market-driven development. It warns of a future where convenience overrides public oversight and emotional infrastructure is outsourced to

opaque algorithms. Strategic autonomy, epistemic integrity, and digital citizenship may be at risk unless counterbalanced by systemic intervention.



As a reminder, these are the three scenarios, including a few keywords (in brackets):

1-Developing our ambidexterity (supervised creativity - balance & compromise, co-creation & crowdsourcing)

2-Values will eventually make a difference (ethics by design - safety over convenience - rule of law & transparency)

3-More of the same thing (digital empathy - digital addiction - EU marginalisation)

Fig. 15 - The three scenarios as presented in a reminder slide for Workshop IV's interactive session

4. From Stories to Strategy

The three scenarios developed in the context of the four foresight workshops have not been conceived to generate consensus or forecast outcomes. Instead, they offer divergent vantage points from which to reflect on future institutional, technological, and societal orientations. Their role is heuristic: to stimulate debate, test assumptions, and support articulating strategic options. By presenting futures grounded in distinct value configurations and governance logics, the scenarios help stakeholders evaluate trade-offs between agility and accountability, autonomy and protection, innovation and coherence. They offer starting points for anticipatory governance, including risk identification, priority-setting, and pathway exploration. Their open-ended structure allows selective recombination of features to inform a strategic trajectory, which will be elaborated, proposed in the chapter on the meta-scenario (Chapter 4).

ANNEX II: LIST OF RELEVANT STANDARDS CONSIDERED IN THE FORESIGHT

List of standards to sort out for the interactive exercise of T2.3 workshop 2 (August 29th 2024)

(This mix of 13 standards is a sample, of course, but forcing participants to take decisions on their importance and impact for virtual worlds, with some dilemmas here and there, i.e. their choice showing what they value most, including when some participants do not necessarily know all the technical standards at stake):

VW = Virtual Worlds

• Accessibility Standards	Standards that must ensure accessibility of Web content and virtual environment for all types of users, including with disabilities (for instance, the **WCAG2.0**, which have become ISO : **ISO/IEC 40500:2012**).
• HTML5	The latest version of HTML, can help manage VW configurations and support the user interface experience, third-party APIs being integrated into this standard, such as **WebGL**, from the Khronos Group to add videos and 3D content to pages.
• glTF	A standard for 3D models, ensuring consistent rendering across different platforms, said to be the "JPEG of 3D".
• 5G/6G	Standards and protocols for high-speed, high throughput and low-latency internet communication.
• MPEG-DASH	Dynamic Adaptive Streaming over HTTP (DASH), an adaptive streaming technique that enables high quality streaming of media content over the Internet, delivered from conventional HTTP web servers.
• IoT standards	The Internet of Things, a brick of VWs, is involving a large variety of standards, in particular to ensure interoperability, security, and efficient data management.
• Cybersecurity standards	There are many standards meant to support that domain, not necessarily linked to VW, for which at least **OAuth 2.0** and **OpenID Connect,** for authentication and authorization, are important.
• Interoperability standards	Among many more specific standards for technological bricks, for VWs, the main integration standards are :

	1) **OpenXR:** for VR and AR application interfaces, ensuring applications can run on various hardware, 2) **WebXR:** for experiencing VR and AR on web browsers, enabling cross-platform experiences, 3) **glTF (GL Transmission Format):** for 3D models, ensuring consistent rendering across different platforms
• Legal standards	There are many legal standards (e.g., IPR laws or Content Moderation and Hate Speech Laws), but let's mention three of them, important for VWs: **1) GDPR (General Data Protection Regulation):** Standards for data protection and privacy in the European Union. **2) COPPA (Children's Online Privacy Protection Act):** US Regulations for protecting the privacy of children under 13 in the U.S. **3) Content Moderation Policies:** Standards for acceptable behaviour and content within virtual environments.
• FBX and OBJ	Formats for 3D models
• Universal Scene Description format (USD)	A framework for interchange of 3D computer graphics data.
• COLLADA	For "Collaborative Design Activity" : an interchange file format for interactive 3D applications.
• Fair economic practice, including transparency in virtual transactions	Many standards are here at stake, e.g., **Anti-Money Laundering (AML)** and **Know Your Customer (KYC) Regulations, or Consumer Protection Laws and for fair practice, the brief** Fairness and transparency for business users of online services (europa.eu)**.**

ANNEX III: LIST OF EXPERTS WHO PARTICIPATED IN THE WORKSHOPS

Name	Surname	Bio	Country
Mohsan	Ali	Interoperability Researcher in Open Data Ecosystems (Big, Linked, and Open Government Data)	Greece
Federico	Anselmi	Project and Community Manager at XR4Europe Coordinator IMPULSE Funding Market at VRDays' Immersive Tech Week - Producer at IFFR Pro Immersive	Italy
Michael	Barngrover	Consortium Member	Belgium
Raffaele	Battaglini	Founder of an international law firm specialising in technology and innovation, providing legal expertise for AI, blockchain, and emerging tech industries.	Italy
Paulina	Behluli	Independent expert in data policy, with a focus on leveraging data-driven insights to shape policy and governance frameworks for emerging technologies.	Belgium
Matilde	Beltrandi	Young cybersecurity leader in the private sector, specialising in the intersection of IT infrastructure and advanced data protection methodologies.	Italy/France
Devis	Bianchini	Professor of information engineering at the University of Brescia	Italy
Ian	Biscoe	Dr Ian Biscoe works at Design Academy Eindhoven as a visual and performance artist, director, producer, entrepreneur, designer and engineer with degrees in architecture and landscape architecture. His research practice combines the arts and technology, employing a transdisciplinary approach that draws on his background in science, systems integration, technology, architecture, performing and visual arts, design, and business.	The Netherlands
Anda	Bologa	Young international expert in AI and digital policy, focusing on the ethical and societal implications of artificial intelligence in governance and innovation.	Romania
Aleksander	Burkiewicz	Consortium Member	Belgium
Julien	Castet	Julien Castet has been leading research activities at Immersion since 2012. His main areas of expertise are interaction, virtual reality, augmented reality, mixed reality, computer music, human-computer interaction and art. He is an active expert with the French National Research Agency and the European Commission. Before taking up his current post, he conducted	France

Name	Surname	Bio	Country
		research into 3D interaction and haptics at the Grenoble Institute of Technology.	
Iannis	Charalabidis	Yannis Charalabidis is Professor of Digital Governance in the Department of Information and Communication Systems Engineering of the University of Aegean. In parallel, he serves as Director of the Innovation and Entrepreneurship Unit at the University, designing and managing youth entrepreneurship activities, and as Head of the Digital Governance Research Centre, coordinating policy-making, research, and pilot application projects for governments and enterprises worldwide. He has over 25 years of experience in designing, implementing, managing, and applying complex information systems as a project manager in Greece and Europe. He has been employed for 10 years as an executive director in SingularLogic Group, leading software development and company expansion in Greece, Eastern Europe, India and the US.	Greece
Veronica	Cretu	Veronica Cretu is President of the "CMB" Training Centre, Moldova. Her background is in Diplomacy and IT, with the Mediterranean Academy of Diplomatic Studies of Malta. In April 2013, Mrs. Cretu was elected as a civil society Steering Committee Member of the Open Government Partnership. She is currently a member of the Multi-stakeholder Advisory Group to the Internet Governance Forum, a UN structure. Veronica is also a member of the Nominating Committee of the Internet Corporation for Assigned Names and Numbering (ICANN).	Moldova
Valeria	De Antonellis	Esteemed computer science professor and academic authority in data systems, with a legacy of research and education in technology innovation.	Italy
Isabella	de Magny	Consortium Member	Switzerland
Galileo	Disperati	Consortium Member	Switzerland
Adam	Doulgerakis	Senior R&D Technical Project Manager at Athens Technology Centre with 10+ years of experience in the implementation and management of EU and national ICT research and development projects, in the coordination of international consortia of partners and in the engineering of research proposals.	Greece
Arta	Ertekin	Consortium Member	Switzerland
John	Favaro	Consortium Member	Italy
Claudio	Feijoo Gonzales	Full Professor at Universidad Politécnica de Madrid and Jean Monnet Chair of Technology Diplomacy	Spain
Venere	Ferraro	Consortium Member	Italy

Name	Surname	Bio	Country
Valerio	Frascolla	Valerio Frascolla (MSc and PhD in Electronic Engineering) is a curious spirit, scouting new technologies and assessing their societal impacts, currently working as Director of Research & Innovation at Intel and as evaluator for the European Commission, Portuguese, Rumanian, Latvian and Cypriot funding agencies, and for open calls of numerous EU-funded projects.	Italy
Karlo	Funk	Experienced film and TV professional with a demonstrated history in film funding, content acquisitions, project management and curating programmes.	Estonia
Marco	Galvagno	As Deputy Rector for Promotion & Marketing, I hold a Ph.D. in Management and a Laurea Degree in Business Economics from the University of Catania, where I teach Marketing and Digital Marketing to undergraduate and graduate students. I held a visiting position as research scholar at the Mays Business School, College Station, Texas A&M University, (US).	Italy
Sergio	Giorgio	Describes himself as a (freelance) tech innovator and dreamer.	Italy
Gabriel	Gonzalez	Consortium Member	Spain
Giacomo	Inches	Consortium Member	Switzerland
Iva	Junakovic Prazen	AI project leader with a background in managing cross-border initiatives aimed at fostering cultural exchange and technological innovation.	Belgium
Sönke	Kirchhof	Sönke Kirchhof is CEO and executive producer of award-winning VR Full Service Studio INVR.SPACE GmbH. He studied political science in Hamburg and Film and TV Production at Filmuniversität Babelsberg. He has worked in the fields of VR, stereoscopic filmmaking, VFX, and CGI Post-Production, as well as Research and Development in arts and technology, for over 20 years. In addition to content production, Sönke is actively engaged as a speaker and lecturer at festivals and institutions, as well as a member of regional and international XR associations, to increase the visibility and strength of the XR industry.	Germany
Barbora	Kudzmanaite	Experienced EU policy advisor, specialising in digital transformation, the platform economy, emerging technologies, and other topics at the intersection of digital and policy, working for PPMI (Lithuania) in Belgium	Belgium
Eugenia	Kypriotis	Consortium Member	Switzerland

Name	Surname	Bio	Country
Francesco	Lapenta	Foresight expert and member of the UN Task Force on Digital, contributing insights into the strategic role of emerging technologies.	Italy
Ilaria	Mariani	Consortium Member	Italy
Gianluca	Misuraca	Consortium Member – Lead Foresight Expert	Switzerland
Francesco	Mureddu	Consortium Member	Belgium
Matteo	Nicolosi	Consortium Member	Switzerland
Jana	Novohradska	Expert in AI and digital governance, with a focus on ethical frameworks and policy development for emerging technologies.	Slovak Republic
Francesco	Panella	Consortium Member	Italy
Anestis	Papadopoulos	Owner and Director of Platon Schools, CSO at Pi-tech, Chair of the School Education Working Group - Dlearn Member of Advisory group - Education for Climate Coalition. Coordinator in European projects, specialised in School Management, Physics teaching, New Technologies in Education, Design, Development of learning and teaching activities, Monitoring and evaluation of school processes.	Greece
Christine	Perey	Christine Perey is an independent consultant with nearly 30 years of experience serving clients in emerging technology markets.	Switzerland
Juha	Pihanen	Finnish-born producer (media, IT, theatre, sports, events), actor, singer and farmer, back in Hollola, Finland, after 17 years abroad (NYC, Berlin, London).	Finland
Pierre	Plouzennec	Foresight and innovation specialist, leading strategic initiatives to drive technological advancements and sustainability in industrial operations.	Switzerland
Lukasz	Porwol	Consortium Member	Poland
Arjun	Rai Gupta	Project and Cluster Manager, Visual Dimension Centre, Fellbach, Germany	Germany
Pierre	Rossel	Consortium Member – Lead Foresight Expert	Switzerland
Caroline	Rudzinska	Industry leader in XR, 5G, and mobile technologies, driving advancements in next-generation communication and immersive digital experiences.	Germany
Wouter	Schuur	Wouter Schuur has skills like Interaction Design, User Interface Design, User Experience, Front End, Web Design, Usability, and Web Development	The Netherlands

Name	Surname	Bio	Country
Bianca	Severin	Multimedia Developer and Architect based in Vienna, Austria. I create technical solutions, 3D tools and VR experiences to make complex urban data and scenarios accessible. My focus is on facilitating clear communication in participatory processes, enabling all stakeholders to understand and shape their environments. Open to new ideas, interdisciplinary collaboration, and exploring the full potential of digital tools in urban contexts.	Austria
Vana	Stavridi	Vana Stavridi studied Philosophy and Social Sciences at the University of Crete. She further studied Philosophy and the Epistemology of the Social Sciences (MA) and received an excellence award. As an MA student, she was a member of 'Laboratory of Philosophical Research and Translation' at the Department of Philosophy and Social Studies in the School of Philosophy of the University of Crete. During her PhD research, she focused on contemporary Political Philosophy and Social theory.	Greece
Shani	Tiran	Consortium Member	Germany
Mattia	Trino	Consortium Member	Italy
Abdul	Wahid	Consortium Member	Ireland
Marcin	Wałęsa	Experienced Project and Program Manager working in these positions for 6+ years in an international company. As a member of the PMO, I'm responsible for planning and monitoring multiple programs and projects simultaneously, coordinating the efforts of distributed teams.	Poland
Matthieu	Worm	Distinguished Key Expert at Siemens, leading the initiation of the European partnership for Virtual Worlds and the associated Strategic Research & Innovation Agenda with the European Commission. Strengthening Siemens' position as the innovation leader in the domain of simulation & digital twin Driving consistency and coherence in the research and technology roadmap of Siemens Technology's Simulation & Digital Twin group, making the lifecycle digital twin a reality in end-user applications, while continuously incubating new ideas and concepts for the future, like the industrial metaverse.	France