Citiverse Initiative

Global Initiative on Virtual Worlds and AI – Discovering the Citiverse

Citiverse Use Case Taxonomy: Economic Development, Education and Tourism

Foreword

This publication was developed within the framework of the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*, which is a global multistakeholder platform launched by the International Telecommunication Union (ITU), the United Nations International Computing Centre (UNICC), and Digital Dubai, and supported by more than 60 international partners.

The Initiative aims to shape a future where AI-powered virtual worlds are inclusive, trusted, and interoperable. By connecting people, cities, and technologies, it empowers meaningful progress through AI-powered virtual worlds.

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Disclaimers

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations, Executive Committee members or Steering Committee members of the Initiative. The findings presented in this report are based on a comprehensive review of existing literature and voluntary written contributions submitted by a diverse range of stakeholders.

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Citiverse Use Case Taxonomy: Economic Development, Education and Tourism

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Abbreviations and acronyms

AI	Artificial intelligence
AR	Augmented reality
BIM	Building information modelling
GAI	Generative artificial intelligence
GenAI	Generative artificial intelligence
GIS	Geographic information system
GPS	Global positioning system
ICT	Information and communication technology
IoT	Internet of Things
MR	Mixed reality
MVP	Minimum viable product
NGO	Non-governmental organization
ROI	Return on investment
SDG	Sustainable Development Goal
SITE	Social Interactive Twin Economy
VR	Virtual reality
XR	Extended reality

1. Introduction

This report is part of a series produced under the Use Case Identification Track of the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*. To make the taxonomy more accessible and user-friendly, the material has been presented as one overarching report and five thematic reports.

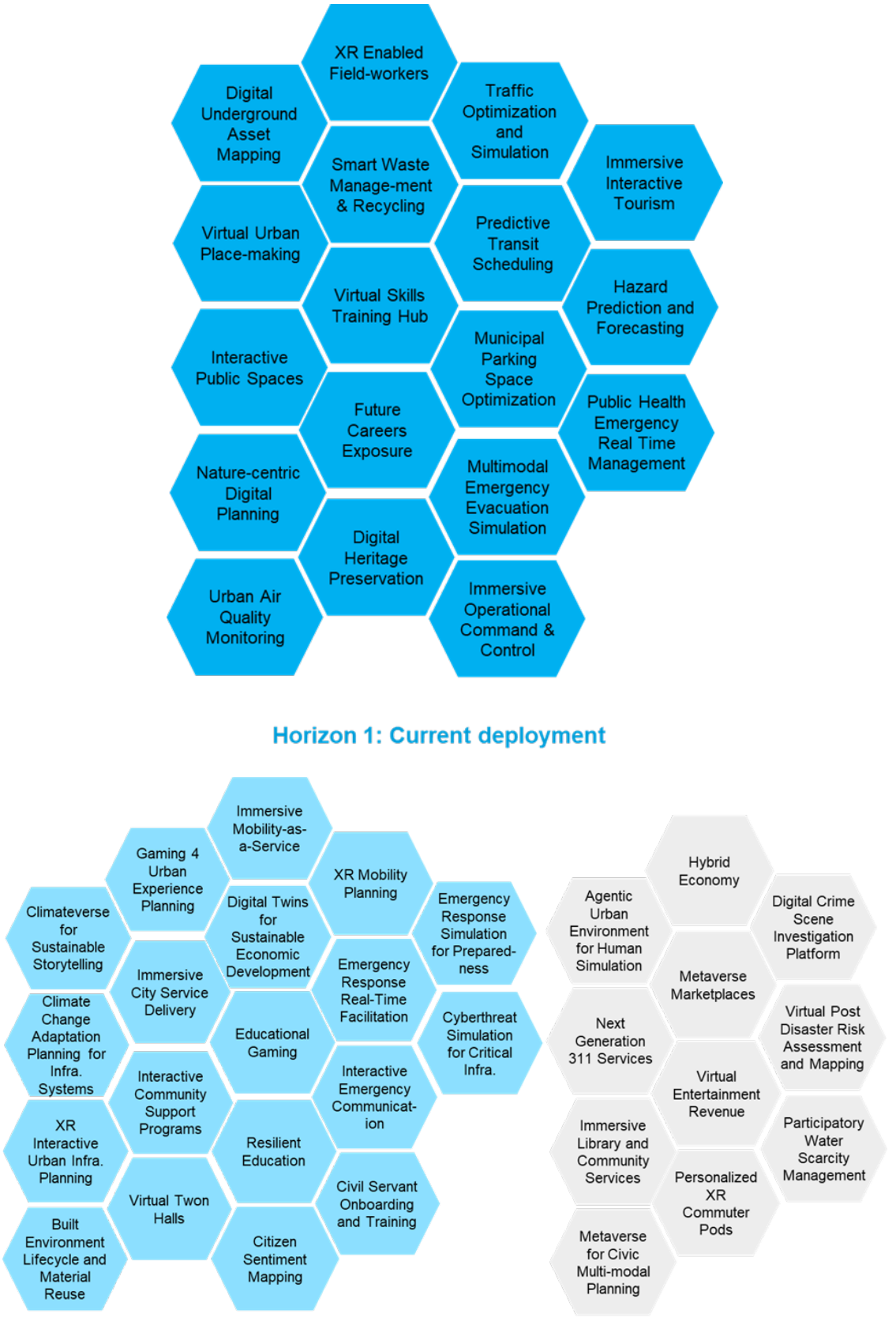
This thematic report focuses on economic development, education and tourism. It includes the overall taxonomy for reference, a thematic overview, detailed use cases, and concluding information about the Initiative and references.

The Global Insights and Implementation Pathways report provides the overarching framework, while the other thematic reports cover the remaining four areas. Together, these reports provide both a global framework and sector-specific insights, supporting decision-making for policymakers, industry leaders, and city practitioners.

2. Overall use case taxonomy

The Citiverse Use Case Taxonomy provides a consolidated overview of nearly 50 use cases spanning five thematic areas. Figure 1 presents the overall use case landscape and horizon mapping. This overarching taxonomy highlights the interconnections between domains and demonstrates how emerging technologies can be applied across multiple aspects of urban life. Within this broader framework, the following section focuses on the thematic area of economic development, education and tourism.

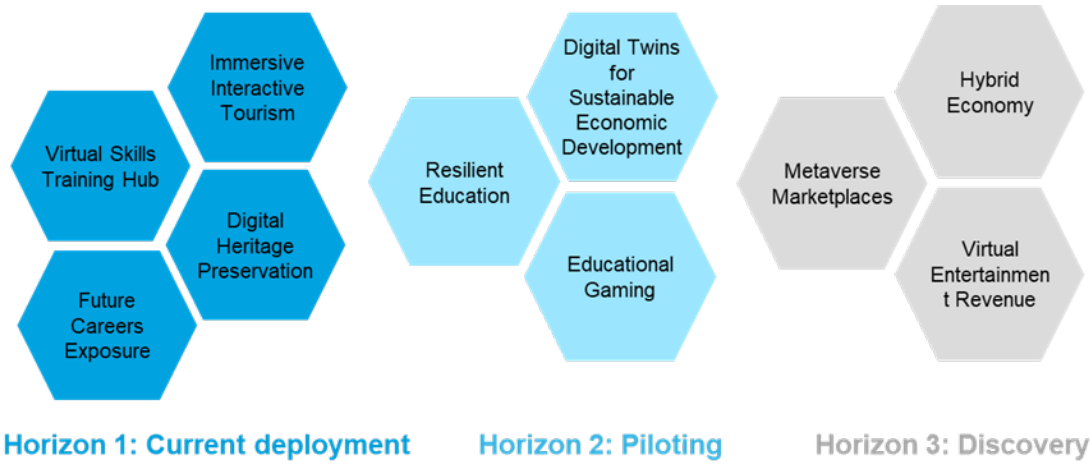
Figure 1 Overall use case overview and horizon mapping



Source: Citiverse Use Case Taxonomy: Global Insights and Implementation Pathways, 2025

3. Economic development, education and tourism

Figure 2 Economic development, education and tourism use case taxonomy & horizon mapping



Source: Citiverse Use Case Taxonomy: Economic Development, Education and Tourism, 2025

3.1 Thematic area description

As a result of the rapid technological advancement environment we are living in, our society is being transformed at an unprecedented rate, leaving cities to adjust to this evolution. Our education system no longer responds adequately to the need for immediacy in accessing and absorbing knowledge from anywhere at any time, cities are struggling to boost sustainable economic development, and the benefits of tourism are facing a reality check over its long-term impact on the environment and urban planning shortfalls.

The thematic of education, economic development and tourism focuses on leveraging the confluence of digital and physical environments to transform how cities address the experiences and interactions of people with their learning, leisure, professional and business surroundings in a more effective way. The use cases will include the following areas:

In relation to education:

- **Resilient education**: Embracing continuity ensuring students remain effectively learning and able to conclude their studies beyond geographical limits, wars/conflict zones, *force majeure* events or other external factors.
- **Immersive education**: Creating immersive education experiences, historic reconstruction scenarios, improving student engagement, learning outcomes and facilitating career choices (e.g., virtual field trips, simulations).
- **Personalized learning/inclusivity**: Developing content to individual student needs, catering for students with learning difficulties and disabilities and democratizing access to advanced technologies fostering equitable educational opportunities across society.
- **Fostering expansive collaboration:** Beyond the classroom, encouraging students to leverage technology with a "without borders" approach by working together in the same immersive location.

In relation to economic development:

- **Blue economy**: Utilizing immersive technology to optimize economic activities related to oceans, rivers, waterways and coastal cities.
- **Circular economy**: Leveraging technology to optimize resource use fostering a "re-use" mindset in cities.
- **Human remote hubs employment**: Amplifying human potential through technology, building up on individual talents, innovation and remote collaborations to create new sources of income by doing more with less.
- **Economic forecasts:** Empowering organizations with information in real time, allowing them to anticipate market shifts, timings, investment and maintenance needs, and to allocate resources and to experience different strategies and management scenarios before making their decisions.
- **Trust transactions**: Building trust through immersive technologies as main drivers of economic development.

In relation to Tourism:

- **Indigenous heritage and culture preservation:** Recognizing the value of indigenous heritage, bringing to life the storytelling across generations, indigenous identity, language and culture through immersive technologies.
- **Creating experiences**: Optimizing tourism experiences fostering stronger connections and customized visitor experience, whilst enhancing local businesses revenue by helping businesses plan and allocate resources effectively. Experiences that can be fully experienced in person or virtually that encourage physical activity and cultural learning through gamification.
- **Real-time assistance**: Technologies that can provide real-time information and assistance to tourists, as well as real-time language translation facilitating communication between tourists and locals.

These thematic areas will prioritize use cases that support the implementation of the SDGS, including Target 8.2 *"Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors"* and Target 12.b "*Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products."*

In summary, to effectively address the changing needs of society, cities are called to integrate emerging technologies with humanity, sustainability, creativity and willingness to make the difference. In the areas of education, economic development and tourism applying artificial intelligence, virtual reality, augmented reality and digital twins' technologies will foster a better and more effective decision-making process in real time, will reduce time, cost and the environmental impact of development, whilst creating experiences instead of merely reacting to them. This can transform communities by providing an unparalleled opportunity to redefine value, drive innovation and maintain the delicate balance between economic imperatives and human needs.

3.2 Economic development, education and tourism use cases

Use case 1: Resilient education (Horizon 3)

Description

Utilizing technology in education can unlock a truly global learning system, empowering new generations to access a right that should be available to all regardless of geographical or socio-economic limitations. Furthermore, education in the digital can be easily adapted and customized to withstand any factors which compromise or interrupt accessibility to learning.

One such factor is war. Although International law protects access to education, even in conflict regions, the truth is that during emergencies and in the midst of destruction of schools and universities, survival becomes the first priority, and, education, as well as dreams are often shattered in the struggle for survival.

Virtual worlds can offer a solution through immersive and interactive environments for students affected by situations of crisis or emergencies, be it for conflict, wars or natural disasters, whereby, the basic human right to education is disrupted by external factors. Through creating alternative pathways to connect students and tutors at global level, the disruptive impact on education can be reduced not only allowing students to complete their studies but also serving as a support system during the rebuilding and recuperation phases.

Digital education programmes area already in place, for example, Academics for Gaza run remote classes led by academic volunteers from around the world;[1] however, immersive technologies have not yet been integrated into these digital education programmes.

Impacts

1) **Quality education**: Virtual learning platforms can deliver high-quality educational content that maintain curriculum standards even during disruptions. Digital twins of classrooms and metaverse-based learning environments ensure pedagogical continuity, allowing students to progress through their studies without compromising academic standards. AI-powered personalized learning can adapt to individual needs, ensuring every student receives quality instruction regardless of their circumstances.
2) **Reduced inequalities:** Virtual education platforms can break down geographic and socio-economic barriers that traditionally exclude vulnerable populations from accessing quality education. By providing Internet-enabled learning opportunities, these systems ensure that displaced students, those in conflict zones, and marginalized communities can receive the same educational opportunities as their peers in stable environments.
3) **Peace, justice and strong institutions:** Education serves as a foundation for building peaceful societies by promoting critical thinking, tolerance, and civic engagement. Virtual learning environments create safe spaces for cross-cultural dialogue and understanding, fostering the values necessary for sustainable peace.
4) **Humanitarian assistance:** Virtual education platforms can provide immediate humanitarian relief by maintaining educational services when physical infrastructure is destroyed or inaccessible.
5) **Health and wellbeing:** Continued access to education during crises can help provide stability and structure for affected students. The social connections maintained through digital platforms help combat isolation and depression common among displaced populations.

6) **Citizen engagement:** Virtual education platforms can create opportunities for global volunteers to support crisis-affected students through mentoring, tutoring, and peer support programmes. These initiatives foster international solidarity and provide meaningful ways for citizens worldwide to contribute to educational resilience in conflict zones.

Key beneficiaries

- Students
- Teachers and educators
- Community organizations and NGOs

Key technologies

- **Metaverse:** Enables virtual classrooms and campus environments that mirror real-world schools, supporting global student and tutor interactions.
- **AR:** Can provide on-site or offline overlays on printed materials or basic devices, offering contextual lesson prompts, language support, and interactive quizzes.
- **VR:** Can enable immersive simulations of laboratories, historic sites, and cultural environments for hands-on learning and field-trip experiences.
- **GenAI/AI:** Can support personalized lesson planning, multilingual real-time translation, adaptive assessments, and AI-driven tutoring and psychosocial support chatbots.

SDG alignment

- **SDG 4: Target 4.5** Eliminate gender disparities in education and ensure equal access for the vulnerable.
- **SDG 4: Target 4.4** Increase the number of youth and adults with relevant skills.
- **SDG 10: Target 10.2** Empower and promote social, economic and political inclusion.
- **SDG 10: Target 10.3** Ensure equal opportunity and reduce inequalities.

Risk level

Table 1 Risk level: Resilient education

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	While virtual platforms minimize physical risks, there are concerns about online safety, data protection of minors, and potential misuse of platforms for harmful activities. Robust content moderation and child protection protocols are essential.
Stakeholder acceptance	Low	Medium	High	Implementation faces resistance from traditional educators, parents unfamiliar with digital learning, and communities that prefer face-to-face instruction. Success requires extensive stakeholder engagement and demonstration of educational effectiveness.
Data privacy and security	Low	Medium	High	Handling sensitive personal data of vulnerable populations, including minors in crisis situations, requires strict compliance with international data protection standards. Cross-border data flows and varying regulatory frameworks increase complexity.
Financial/ operational	Low	Medium	High	High initial investment in technology infrastructure, ongoing maintenance costs, and need for technical support staff. However, long-term scalability and reduced physical infrastructure requirements can offset costs.

Implemented in:

N/A

Case study

For this use-case, no relevant case study has been identified due to the horizon 3 level.

Use case 2: Virtual skills training hubs (Horizon 1)

Description

Many cities are facing significant employment challenges such as skills shortages, with the gap between demand and labour capacity widening, particularly in growing sectors. Combining immersive technologies in key skills training helps to bridge the gap quicker by building skilled workforce or re-skilling existing workforce in specifically targeted skills more rapidly.

By offering flexibility, portability, immersivity, and realistic simulations, these virtual skills training hubs allow learners to experience and safely practice new skills while gaining industry-standard qualifications or licensing. Virtual skills training hubs can accelerate vocational training, break down barriers to employment, communication or cultural sensitivity and address continuing upskilling necessities with tailored training modules and workplace safety and regulations.

Enabling also the creation of new opportunities for jobs in growing sectors, supporting sustainable economic development and access to skills development for under-represented groups, helping to bridge economic disparities and focusing on necessary skills for an evolutive and sustainable future.

Impacts

1) **Reduce poverty:** Virtual Skills Training Hubs offer low-cost, scalable training that removes financial and geographic barriers for low-income learners. By enabling remote access to industry-aligned simulations and certifications, these platforms empower individuals to secure higher-paying jobs and break cycles of poverty.
2) **Quality education:** Immersive VR and AR modules deliver standardized, industry-approved curricula that maintain pedagogical rigor across locations. AI-driven adaptive learning tailors content to individual progress, ensuring every learner achieves competency benchmarks and gains recognized qualifications.

3) **Decent work and economic growth:** These hubs bridge skills gaps in high-demand sectors by providing rapid, hands-on training aligned with employer requirements. Partnerships with industry bodies facilitate direct pathways from virtual training to job placements, driving local economic development and supporting sustainable growth.
4) **Reduced inequalities:** Flexible, accessible training solutions address the needs of marginalized groups – such as NEET youth, caregivers, and people with disabilities – by eliminating physical attendance requirements. Blockchain-based credentialing ensures transparent recognition of skills, fostering equal opportunity in recruitment.
5) **Sustainable cities and communities:** By reducing the need for physical infrastructure and commuting, virtual hubs lower carbon footprints and support compact urban development. Focused training in green technologies – such as renewable energy installation – builds local capacity for climate-resilient industries and sustainable livelihoods.
6) **Climate action:** Immersive simulations train workers in renewable energy, energy-efficient construction, and environmental monitoring, directly contributing to mitigation and adaptation goals. Real-time scenario modelling helps policymakers and learners understand climate impacts and implement evidence-based strategies for a low-carbon future.

Key beneficiaries

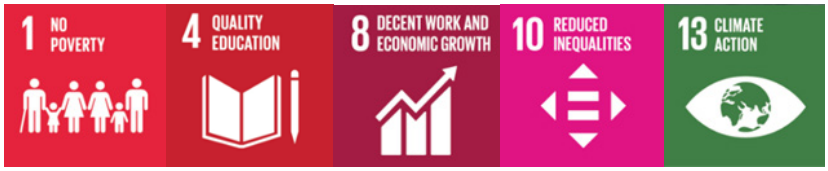
- Local and regional workforce
- Unemployed adults and jobseekers
- Young people (16–24) not in education, employment or training (NEET)
- Mid-career changers and those leaving declining industries
- People with disabilities or caring responsibilities seeking flexible training
- Colleges and local high schools seeking pathways to vocational education
- Sectoral qualification bodies through certification delivery
- Industry and employers
- Government and policy bodies
- Community and civil society
- Academic and research institutions

Key technologies

- **VR:** Can enable immersive training simulation and career exploration environments for young people and career changers.
- **AR:** Can support on-site digital overlays for instruction and live guidance during physical training or assessments, accessibility enhancements (e.g., AR visual or auditory assistance for neurodiverse learners), and be used in outreach environments for live demonstrations and learning support.
- **MR:** Combines real-world elements with digital simulations for more advanced safety and operational training.
- **Digital twins:** Virtual replicas of physical infrastructure (e.g., wind turbines, port environments) for operational training.
- **AI:** Can enable learning analytics to support adaptive learning environments that can track learner progress and tailor training in real-time and support personalised learning journeys aligned with individual career goals and capability levels.

- **Blockchain:** Could be leveraged for credentialing, learner portfolios, and transparent micro-credentialing.

SDG alignment



- **SDG1: Target 1.2** By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.
- **SDG 4: Target 4.3** By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
- **SDG 4: Target 4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.
- **SDG 4: Target 4.5** By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including people with disabilities, indigenous peoples and children in vulnerable situations.
- **SDG 8: Target 8.3** Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.
- **SDG 8: Target 8.5** By 2030, achieve full and productive employment and decent work for all women and men, including for young people and people with disabilities, and equal pay for work of equal value.
- **SDG 8: Target 8.6** By 2020, substantially reduce the proportion of youth not in employment, education or training.
- **SDG 10: Target 10.3** Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard.
- **SDG 13: 13.3** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Risk level

Table 2 Risk level: Virtual skills training hubs

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The project involves activities or environments where there is a relatively low risk of injury (e.g., immersive training simulations). While safety protocols are in place, some exposure to risk remains and must be actively managed through training, monitoring, and health and safety compliance.
Stakeholder acceptance	Low	Medium	High	Projects to date have demonstrated minimal resistance or reputational concern, and engagement mechanisms are already established and functioning well.
Data privacy and security	Low	Medium	High	Projects can handle personal and potentially sensitive data (e.g., learner identities, progress tracking, outreach records). While data protection policies are in place, the integration of XR and cloud-based platforms requires ongoing vigilance and updates to security measures.
Financial/ operational	Low	Medium	High	There is a moderate risk of financial or operational disruption such as cost overruns, inflation, or supply chain issues. While mitigation strategies (e.g., contingencies, phased procurement) are established, careful project oversight is required to stay on track.

Implemented in:

Grangemouth, UK; Newcastle, UK; Kingswinford, UK; Massachusetts, USA

Case study – TRACE VR training for the green energy sector in Scotland

Context

TRACE creates new opportunities for high-quality jobs in the growing green energy sector, supporting sustainable economic development and access to skills development and green energy jobs. The case study was undertaken in Grangemouth in Scotland, where 15% of residents live in the most deprived Scottish Index of Multiple Deprivation (SIMD) areas.

The TRACE Centre is a state-of-the-art facility designed to rapidly train, retrain and upskill workers focusing on renewable energy and green industrial sectors in alignment with Scotland´s Net Zero ambitions. By Combining immersive virtual reality (VR) and augmented reality (AR) with industry-standard offshore safety training, TRACE addresses urgent skills shortages at local, regional and UK-wide levels. By transforming under-utilized industrial land into a vibrant training hub, & providing mobile XR training equipment for outreach projects, TRACE promotes inclusivity and accelerates Scotland's transition to Net Zero, positioning Grangemouth for excellence in industrial skills training innovation.

(continued)

Case study – TRACE VR training for the green energy sector in Scotland

Objective

The primary objective of TRACE is to create a comprehensive XR-enabled training ecosystem that supports Scotland's just transition to a Net Zero economy while addressing critical skills shortages and social inequalities. The key objectives of the project are to promote inclusivity, efficiency, and innovation in green skills development.

- **Skills development and just transition:** TRACE addresses urgent labour shortages in renewable energy, offshore wind, hydrogen logistics, and green transport by providing accelerated, industry-aligned training pathways. The facility specifically targets workers transitioning from high-carbon industries (particularly oil and gas), ensuring no one is left behind in Scotland's Net Zero transition.
- **Poverty eradication and social inclusion:** Asset owners and communities need accessible, high-quality training that removes traditional barriers to employment. TRACE provides free or subsidised XR-based training directly in deprived communities, ensuring equal access to economic opportunities and building long-term resilience for vulnerable populations previously excluded from green economy jobs.
- **Digital innovation and scalability:** The project pioneers the use of extended reality technologies in vocational training, creating replicable methodologies that can be scaled across Scotland and internationally. TRACE's mobile XR units and cloud-based platforms ensure geographic barriers don't limit access to cutting-edge training.
- **Employer engagement and economic growth:** Local employers and industry bodies need a skilled workforce equipped with sector-specific competencies. TRACE co-designs training content with major energy companies, certification bodies (OPITO, GWO), and further education institutions to ensure direct pathways from training to employment, stimulating local economic development.
- **Community regeneration:** Grangemouth requires transformation of under-utilized industrial land into vibrant community assets. TRACE serves as a catalyst for broader regeneration, working in partnership with Falkirk Council and community groups like Greener Grangemouth to ensure local ownership and sustained impact.
- **International leadership:** Scotland aims to position itself as a global leader in climate-conscious workforce development. TRACE demonstrates how immersive technologies can accelerate skills acquisition while promoting social inclusion, creating a replicable model for international adoption in support of global Net Zero goals.

Solution approach

The TRACE Centre delivers a modular, flexible approach to immersive training using extended reality (XR), enabling learners to gain sector-relevant skills quickly and accessibly. Training content (covering areas such as offshore safety, hydrogen logistics, green transport, and marine operations) is delivered through a blend of VR and AR. This is supported by mobile XR units for remote delivery, ensuring outreach to underserved communities. TRACE's approach reduces dependency on traditional classroom infrastructure and accelerates the transition from training to employment, especially in sectors facing urgent labour shortages.

Results

TRACE is already achieving strong traction through local and national partnerships. Mobile VR training equipment has been fast-tracked and deployed in collaboration with community groups such as Greener Grangemouth, allowing early engagement before the main facility is complete. The centre is forecast to train more than 1 200 individuals in its first three years, including upskilling existing oil and gas workers, delivering entry-level offshore safety qualifications, and supporting green logistics operations. TRACE has also received recognition at international level, validating its relevance as a replicable model for skills innovation in support of Net Zero goals.

(continued)

Case study – TRACE VR training for the green energy sector in Scotland

Lessons learned

Key lessons include the importance of integrating employer input from the outset, allowing TRACE to align training directly with real recruitment demand. Early-stage deployment of mobile XR equipment has proven vital for building community trust and identifying access barriers early. Collaboration with further education institutions such as Forth Valley College has demonstrated that immersive learning does not replace traditional pathways but complements them, providing fast-track access to jobs, while preserving long-term education opportunities. Ensuring inclusion (particularly through decentralised outreach) has been critical in improving uptake and ensuring equitable benefits.

Conclusion

TRACE offers a transformative approach to delivering Net Zero-aligned skills at pace and scale. By combining immersive XR training with strategic partnerships and a deep commitment to inclusion, TRACE positions Grangemouth as a national leader in sustainable workforce development. Its early results and international recognition demonstrate local value and global relevance – ensuring that Scotland remains at the forefront of climate-conscious economic growth.

Use case 3: Future careers exposure (Horizon 1)

Description

With the transformation of today´s work environment and emerging technology, the future of work will be substantially different from today´s school curriculum. It's extremely difficult for schools to keep up with the new trends and having staff equipped to teach constantly evolving areas in all schools.

Immersive, hands-on future careers exposure delivered through XR technologies can deliver inspirational education to students and open them to a wider range of career choices in specific emerging fields. By virtually experiencing careers that they wouldn´t otherwise be aware of, or be exposed to, students are empowered to access the diverse range of options and knowledge necessary to follow new fields, and to consider new pathways to career satisfaction and long-term stability. This technology can also open a school´s curriculum to new areas of learning, addressing teacher shortages in specific areas and better serve remote communities. The creation of early awareness and promotion of interest in developing areas can foster preparation for the future of the workforce reducing unemployment rates and focus on addressing future market gaps.

Impacts

This programme creates a variety of different measurable impacts that align with priorities across education, workforce development and sustainability to create an inclusive, future facing and environmentally conscious workforce.

1) **Skill development:** Immersive XR based learning environments equip students with practical, hands on and tailored skills required by the renewable energy sector, particularly offshore wind. Students build technical abilities supported by problem solving skills through the simulation of real-world scenarios.
2) **Workforce readiness:** Curriculum aligned training and exposure to industry specific tools and tasks allow students to be better prepared to enter a growing clean energy workforce. The programme supports readiness for more than three thousand construction jobs and the three hundred permanent jobs expected in the offshore wind sector.
3) **Educational access:** This use case can broaden access to quality STEM education by reaching different student populations that include those in economically disadvantaged regions. Complex concepts are made more accessible and engaging for students using XR tools, which helps bridge education gaps.
4) **Economic growth:** Building a pipeline of skilled workers for a growing industry helps stimulate the local economy through job creation and the long-term career paths those jobs can bring. It helps reduce regional economic disparities by providing youth with stable, high-paying job opportunities in future-proof sectors.
5) **Sustainable awareness:** Through immersive learning students can gain a greater understanding of the environmental challenges and the role of renewable energy plays in meeting those challenges into the future. This awareness fosters generational commitment to climate resilience and sustainability.
6) **Responsible production:** Can support responsible production by training a workforce that is skilled in low impact, environmentally conscious energy practices ensures that clean energy expansion in Australia is supported by an educated labour force that is developed responsibly.

Key beneficiaries

- High school students (especially underserved or regional communities)
- Educators
- Renewable energy employers
- Government agencies (meeting educational, climate and workforce development targets. Promotion of regional equality)
- Industry and Vocational education providers

Key technologies

- **AR:** AR overlays interactive instructions, annotations, and safety information onto real-world tools, environments, or tasks to support hands-on learning, skill development, and remote expert support across diverse career pathways.
- **VR:** VR immerses learners in fully simulated work environments – such as industrial sites or laboratories – for safe, resource-efficient practice of technical and soft skills.
- **MR:** MR headsets merge physical equipment with digital models, allowing learners to execute hands-on tasks and emergency drills with real-time performance feedback and collaborative diagnostics.
- **Digital twin:** Interactive virtual replicas of actual facilities synchronize live operational data, enabling trainees to rehearse workflows, interpret real-time metrics, and co-design processes without risk to physical assets.

SDG alignment

- **SDG 4: Target 4.3** By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
- **SDG 4: Target 4.4** By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.
- **SDG 8: Target 8.5** By 2030, achieve full and productive employment and decent work for all women and men, including for young people and people with disabilities, and equal pay for work of equal value.
- **SDG 13: Target 13.3** Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Risk level

Table 3 Risk level: Future careers exposure

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Minimal physical risk due to delivery being in controlled settings using XR and VR technologies.
Stakeholder acceptance	Low	Medium	High	Close alignment with government educational priorities, community interests and industry requirements make the risk to stakeholder acceptance likely very low.
Data privacy and security	Low	Medium	High	Simulation technologies may require the collection of student data. While standard protections can be applied to data collection the risk of breaches is always moderate and requires continued compliance with regulations and cybersecurity best practices.
Financial/ operational	Low	Medium	High	Initial costs for XR delivery coupled with ongoing maintenance may present operational charges. However, with government support and industry partnerships the mitigation of long-term financial and delivery risks is only moderate.

Implemented in:

Hunter & Illawarra regions, NSW, Australia; New York, USA; Staffordshire, Plymouth, Cambridge, Nottingham, Bradford, Eastbourne, and Leeds, UK

Case study: Extended Reality for STEM Education in New South Wales

Context

Australia's transition to a clean energy future has escalated demand for skilled workers in renewable energy sectors such as offshore wind and sustainable marine development.

The coastal regions of Hunter and Illawarra in New South Wales (NSW) are experiencing rapid growth in renewable infrastructure projects, offering more than 3 000 construction jobs and 300 permanent roles within offshore wind energy development. However, these promising employment opportunities coincide with regional economic disparities and critical skills shortages. To address these challenges, an immersive education programme leveraging extended reality (XR) and virtual reality (VR) technologies has been developed to provide hands-on, engaging career exposure that aligns with the NSW curriculum and promotes equitable access to STEM education. This initiative aims to stimulate long-term workforce development while informing students about sustainability and climate resilience.

Objective

The primary objective of this programme is to equip students, especially those from underserved and economically disadvantaged communities in Hunter and Illawarra, with relevant skills and knowledge to pursue high-paying, stable careers in the renewable energy sector. The programme emphasizes inclusivity, sustainability, and climate change awareness by integrating curriculum-aligned XR/VR-based experiential learning focused on offshore wind and marine energy careers. Key goals include:

- Providing realistic, immersive exposure to clean energy careers to diversify student knowledge beyond traditional classroom methods.

(continued)

Case study: Extended Reality for STEM Education in New South Wales

- Enhancing STEM education access and engagement within regional areas facing economic inequality.
- Aligning educational content with NSW government curriculum standards to ensure relevancy and academic coherence.
- Supporting career pathways for more than 3 000 construction and 300 permanent renewable energy roles projected in NSW offshore wind sector development.
- Promoting understanding of environmental impacts and sustainability principles linked with renewable energy projects to foster climate resilience.

Solution approach

The programme integrates XR and VR technologies to create interactive learning environments that replicate real-world offshore wind and marine energy development scenarios. This approach enables students to gain hands-on experience with industry tools, workflows, and problem-solving activities in a risk-free, immersive virtual setting. Key components of the solution include:

- **Immersive simulations:** VR modules simulate offshore wind farm construction and marine energy operations, allowing learners to virtually navigate sites, perform technical tasks, and visualize renewable energy systems in 3D.
- **AR:** AR overlays provide contextual information and step-by-step guidance during physical classroom activities, enhancing student understanding of complex energy concepts.
- **MR:** MR enables collaborative exercises blending physical models with digital interfaces for teamwork and assessment remediation exercises.
- **Curriculum integration:** Content is directly mapped to NSW STEM curriculum frameworks, ensuring alignment with educational standards and facilitating teacher adoption.
- **Multistakeholder collaboration:** Robust partnerships between regional schools, clean energy industry leaders, and NSW government agencies ensure practical relevance, resource sharing, and strategic outreach.
- **Inclusion and outreach:** Mobile XR kits and digital platform access extend learning opportunities to remote or underserved communities, reducing geographic and socio-economic barriers.

Results

- **STEM engagement and access:** The programme increased STEM access in regional and disadvantaged NSW communities, capturing student interest through immersive and practical learning tools.
- **Skills development:** Students acquired practical skills aligned with real-world renewable energy sector needs, strengthening readiness for positions in offshore wind and marine energy.
- **Workforce pathway creation:** The initiative established clear pathways to more than 3 000 anticipated construction roles and 300 permanent sector jobs, supporting NSW's clean energy workforce expansion.
- **Sustainability awareness:** Participating students gained enhanced understanding of renewable energy's environmental benefits and the importance of sustainable marine development for climate resilience.

(continued)

Case study: Extended Reality for STEM Education in New South Wales

- **Curriculum adoption:** Schools incorporated XR/VR modules as complementary learning tools within STEM curricula, facilitated by NSWhigh school educators and aligned government guidelines.
- **Regional economic impact:** By targeting workforce development in economically challenged areas, the programme contributed to reducing regional disparities and fostering inclusive economic growth.

Lessons learned

- **Sector collaboration enhances relevance:** Close coordination with industry partners ensured the programme met real labour market needs, thus improving student motivation and job placement prospects.
- **Immersive technology boosts engagement:** XR and VR significantly improved student enthusiasm and comprehension compared to conventional STEM teaching methods, especially in remote or underserved areas.
- **Curriculum alignment is crucial:** Mapping learning content to state curriculum standards facilitated teacher adoption and integration, reducing resistance to new technology incorporation.
- **Outreach overcomes access barriers:** Providing mobile XR kits and remote platform access is essential to reach disadvantaged students and ensure equitable participation.
- **Sustainability integration fosters holistic learning:** Embedding environmental impact and climate resilience within career exposure broadened students' perspective beyond technical skills to include responsible production and ecological stewardship.

Conclusion

This immersive education programme in New South Wales effectively bridges the gap between education and industry by employing XR and VR technologies to provide equitable, engaging career exposure in offshore wind energy and sustainable marine development. By aligning with public curricula and targeting underserved regional communities, the initiative supports critical workforce development, economic inclusion, and climate resilience goals integral to Australia's transition to clean energy. The case exemplifies how technology-enabled, collaborative education can help overcome regional disparities and skills shortages, preparing the future workforce for sustainable prosperity.

Use case 4: Digital heritage preservation (Horizon 1)

Description

Global cultural and natural heritage faces growing threats from conflict, disasters, increased tourism, climate change and environmental damage, endangering our shared history. Traditional preservation methods alone are insufficient. Virtual world technologies can support education, research, heritage management, and community sustainability, protecting cultural identity and providing benefits for global scholars, institutions, Indigenous communities and future generations. By providing open access to digital heritage data and detailed 3D and immersive models, cultural and scientific resources can be democratized as a unified world patrimony, ensuring future generations access to their cultural identity and heritage information fostering public engagement worldwide and ensuring that humanity´s history is safeguarded.

Impacts

1) **Quality education:** 3D models and open access digital heritage date help create immersive educational experiences cultural and scientific knowledge more engaging, interactive and readily accessible.
2) **Improved accessibility:** The use of virtual world technologies help break down geographical and physical barriers enabling global audiences greater access and interaction with cultural heritage.
3) **Climate change adaptation:** Digital preservation of vulnerable heritage sites using tools that provide a safeguard against climate related threats ensures that knowledge and culture are not lost in times of changing environmental factors.
4) **Cultural heritage preservation:** Digital documentation provides protection for cultural and natural landmarks against environmental changes allowing for detailed and long-lasting records that help bolster research and intergenerational memory.
5) **Sustainable tourism:** Virtual experiences help reduce the physical real-world strain of over tourism on certain fragile locations. At the same time, it offers new, lower-impact ways for tourists to experience global heritage.
6) **Environmental protection**: Digital vision and education promotes conservation and minimises damages that can be caused by traditional tourism activities.

Key beneficiaries

- Local communities
- Indigenous communities
- Researchers
- Scholars
- Governments

Key technologies

- **Digital twin:** Digital twins create virtual replicas of cultural and natural heritage assets, allowing 3D, geospatially accurate models of sites, objects, and environments to be explored, analysed, and preserved. These dynamic digital models facilitate collaborative research, enable restoration planning, and provide open access for future generations – ensuring history is safeguarded even if the original is lost or damaged.
- **Metaverse:** The metaverse enables the construction of persistent, immersive virtual worlds where users can engage with heritage sites, museum exhibitions, and educational content. Through shared avatars, real-time interaction, and global collaboration, the metaverse supports inclusive participation and democratizes access to heritage experiences previously limited by geography or physical constraints.
- **AR:** AR overlays interpretive information, digital reconstructions, and interactive features directly onto physical heritage sites and objects. Visitors can use smartphones or wearable devices to see historical layers or lost features superimposed in-situ, enhancing education, accessibility and engagement without disturbing the physical environment.
- **VR:** VR immerses users in fully digital recreations of heritage sites, artifacts, and events, making exploration possible regardless of location or mobility limitations. VR experiences allow users to "walk through" ancient cities, participate in historical events, or conduct scientific investigations, all within a controlled, accessible, and repeatable virtual environment.
- **MR:** MR combines real and virtual elements seamlessly, creating interactive heritage experiences that blend tangible artifacts with digital content. MR can be used for guided tours, participatory storytelling, and collaborative restoration projects – bridging physical and digital engagement for education, preservation and inclusion.

SDG alignment

- **SDG 8: Target 8.9** By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products.
- **SDG 11: Target 11.4** Strengthen efforts to protect and safeguard the world's cultural and natural heritage.

Risk level

Table 4 Risk level: Digital heritage preservation

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Activities are non-invasive and controlled with minimal direct interaction with the public during the digitization process. Delivery being in controlled settings using XR and VR technologies further reduces public risk.
Stakeholder acceptance	Low	Medium	High	The project's mission to preserve and share heritage through openly shared data aligns interests from governments, museums, communities and researchers. A collaborative, transparent approach fosters a broader stakeholder support with a low risk to acceptance.
Data privacy and security	Low	Medium	High	Technologies may require the collection of user data. While standard protections can be applied to data collection the risk of breaches is always moderate and requires continued compliance with regulations and cybersecurity best practices.
Financial/ operational	Low	Medium	High	Initial costs for digitization coupled with ongoing maintenance and updates may present operational challenges. However, with government support and industry/commercial (museums) partnerships the mitigation of long-term financial and delivery risks are only moderate.

Implemented in:

New York, USA

Case study: 3D Visualisation through Global Digital Heritage

Context

Global Digital Heritage (GDH) is a not-for-profit organization digitally documenting and preserving cultural and natural heritage using advanced 3D visualization and geospatial technologies. Collaborating closely with governments, museums, scholars, and indigenous communities, GDH safeguards cultural identity and community heritage addressing global threats from conflicts, natural disasters, increased tourism, and rapid environmental change. Global Digital Heritage addresses this urgent need through innovative 3D digital documentation, virtualization, and open-access models preserving and safeguarding a variety of physical sources in their original format.

Cultural sites around the world are increasingly at risk as a result of environmental disasters, conflict and global change which culminates in the threatening of irreplaceable human histories.[2]

(continued)

Case study: 3D Visualisation through Global Digital Heritage

Objective

GDH's mission is to digitally record and protect at-risk cultural and natural heritage assets, creating high-fidelity 3D models and immersive experiences that support:

- **Quality education**: Enabling immersive learning through interactive 3D assets.
- **Accessibility:** Breaking physical and geographic barriers for global audiences.
- **Climate resilience:** Safeguarding records of sites threatened by climate change.
- **Heritage management:** Providing digital twins for restoration planning and research.
- **Sustainable tourism: Offering** virtual experiences to reduce pressure on fragile locations.[3]

Solution approach

GDH implements a multidisciplinary pipeline combining advanced capture technologies, rigorous data processing, and open dissemination:

- **Field data acquisition:** Terrestrial LiDAR scanning and drone-based photogrammetry capture millimetre-level surface detail and full site coverage.[4]
- **High-resolution multispectral imaging:** records material conditions and colour fidelity for conservation analysis.
- **Geospatial integration:** Global Navigation Satellite System (GNSS) and ground control points ensure sub-centimetre georeferencing. GIS platforms align digital assets with environmental and structural monitoring data in real time.
- **3D Reconstruction & digital twin creation:** Point-cloud processing and mesh generation produce watertight, textured 3D models. Digital twin frameworks integrate sensor feeds (e.g., humidity, structural strain) to support condition monitoring and virtual restoration planning. For example, a 3D digital twin was created of Petra's Treasury in Jordan in 2024 using 60 laser scanners and 5 500 photographs.[5]
- **Open-access dissemination:** An online portal publishes 3D assets in glTF and CityGML formats for web-based viewing, VR/AR exploration, and GIS analysis. Metadata follows international standards (ISO 19115) to facilitate interoperability across educational, research, and heritage-management platforms.
- **Community & stakeholder collaboration:** GDH establishes formal agreements with local authorities and Indigenous communities to co-govern digital representations and ensure that cultural protocols and data sovereignty are respected.[6]

Results

- **Global reach:** GDH has documented 300 sites and museum collections across 15 countries, spanning petroglyphs in Sharjah to ancient terracotta fragments in Asciano. 10 000 artifacts have been digitally modelled and conserved.
- **Extensive archive:** The GDH portal hosts 30 000 scans and 3 million photographs – amounting to 180 GB.

(continued)

Case study: 3D Visualisation through Global Digital Heritage

Lessons learned

- **Ethical co-governance:** Early, consent-based collaboration with custodial communities ensures cultural sensitivity, accurate representation, and shared stewardship of digital assets.
- **Open standards for interoperability:** Publishing assets in open formats with standardized metadata accelerates integration into educational platforms, VR/AR applications, and GIS systems.
- **Hybrid preservation model:** Combining digital surrogates with traditional conservation secures virtual and physical heritage against irreversible loss.
- **Scalable workflows:** Portable data-capture kits and automated processing pipelines drive down per-site costs, enabling rapid deployment in remote or under-resourced regions.
- **Virtual tourism multiplier:** Integrating 3D experiences into museum exhibits and online portals expands audience reach offering sustainable tourism alternatives that alleviate physical site degradation.

Conclusion

Global Digital Heritage's technology-driven strategy demonstrates how digital twin creation, open-access distribution, and community co-governance can preserve cultural and natural heritage amid existential threats. By democratizing detailed 3D data and fostering cross-sector partnerships, GDH ensures that future generations can access, study, and celebrate humanity's shared history – pixel by pixel.

Use case 5: Hybrid economy (Horizon 3)

Description

The economic benefits brought by global tourism are being counterbalanced with its environmental impact, geographical inequalities and the pressure on local communities and cities to continue rapid growth rates and unsustainable resource use.

Converging virtual worlds technologies and data analytics to create a twin economy, can empower city stakeholders and local communities to control their physical and digital spaces and their virtual market presence, creating new opportunities to diversify their economy, by virtually showcasing local businesses, nature, sites, traditions and culture, developing ecommerce, sharing experiences/data, explore NFTs and engage in digital currency exchange options. This dual reality/virtual economy platform can provide the opportunity to rebalance inequalities, promote inclusivity and lessen the impact on the environment.

Impacts

1) **Economic growth:** Diverse revenue streams – including virtual tours, digital asset sales, subscriptions, and sponsorships – drive sustained local income, even during physical tourism downturns.
2) **Economic resilience and diversification:** Blending physical and virtual tourism reduces dependence on in-person travel, insulating destinations from environmental disruptions and geopolitical crises.
3) **Environmental protection:** High-fidelity virtual experiences substitute physical visits, cutting carbon emissions and minimizing ecological damage at sensitive sites.
4) **SME growth:** Tokenized souvenirs, virtual tickets, and e-commerce marketplaces expand global market access for small and medium enterprises, bolstering their competitiveness and stability.
5) **Employment opportunities:** Creation and maintenance of immersive platforms generate roles in VR/AR development, blockchain operations, content production, and digital marketing, upskilling local workforces.
6) **Community-driven content stewardship:** Training residents to build and update their region's digital twin ensures local ownership, ongoing relevance, and cultural authenticity in virtual representations.
7) **Cultural reclamation through local narratives:** Community-led storytelling within virtual environments preserves authentic heritage, countering biased or homogenized external narratives.
8) **Immersive learning and educational partnerships:** VR/AR integrations in curricula deliver experiential learning in culture, history, and sustainability, fostering digital literacy and lifelong skills.

Key beneficiaries

- Tourism sector
- Local communities
- Technology and creative industries
- Government and public sector
- General public and travellers

Key technologies

- **VR:** creates immersive, computer-generated 3D environments that users can explore using headsets or web-based portals. These experiences can simulate real-world locations in stunning detail.
- **AR:** overlays digital content onto the real world using devices such as smartphones, tablets, or AR glasses.
- **AI:** AI enables machines to simulate human intelligence, including pattern recognition, decision making, and personalisation.
- **Blockchain:** Blockchain is a decentralised, secure ledger system enabling transparent transactions and ownership tracking.
- **Spatial computing:** Spatial computing blends the physical and digital worlds by understanding and interacting with environments in 3D space.
- **3D Scanning and modelling:** These technologies capture real-world environments using LiDAR, photogrammetry, or depth sensors, converting them into detailed digital twins.
- **Digital twins:** are dynamic, real-time digital representations of physical locations or systems.
- **WebXR and cross-device accessibility:** enables immersive experiences directly through web browsers across devices – desktop, mobile and VR headsets.
- **IoT**: connects physical devices to collect and exchange data in real-time and can feed live environmental or visitor data into digital twins, supports context-aware recommendations and environmental management (e.g., lighting, temperature, or congestion alerts) and integrates with smart tourism infrastructure for enhanced visitor experience.

SDG alignment

- **SDG 4: Target 4.7** Ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development, global citizenship, appreciation of cultural diversity, and culture's contribution to sustainable development.
- **SDG 8: Target 8.2** Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value-added and labour-intensive sectors.
- **SDG 8: Target 8.3** Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalisation and growth of micro-, small- and medium-sized enterprises, including through access to financial services.
- **SDG 8: Target 8.5** Achieve full and productive employment and decent work for all women and men, including for young people and people with disabilities, and equal pay for work of equal value.
- **SDG 8: Target 8.6** Substantially reduce the proportion of youth not in employment, education or training.
- **SDG 8: Target 8.9** By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products.

- **SDG 9: Target 9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being.
- **SDG 9: Target 9.2** Promote inclusive and sustainable industrialisation and, by 2030, significantly raise industry's share of employment and gross domestic product.
- **SDG 9: Target 9.5** Enhance scientific research, upgrade technological capabilities of industrial sectors in all countries, and encourage innovation and the development of new technologies.
- **SDG 10: Target 10.2** Empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status.
- **SDG 10: Target 10.3** Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action.
- **SDG 11: Target 11.4** Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
- **SDG 11: Target 11.7** Provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities.
- **SDG 12: Target 12.b** Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products.

Risk level

Table 5 Risk level: Hybrid economy

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Operating in digital and virtual environments means minimal direct physical impact, but medium risk applies due to potential issues like digital exclusion, screen time, online harassment, or health and wellbeing considerations associated with increased digital engagement.
Stakeholder acceptance	Low	Medium	High	Adoption may encounter moderate resistance depending on digital literacy levels, access to technology, and trust in virtual or hybrid economic models, despite general alignment with inclusivity and local empowerment goals.
Data privacy and security	Low	Medium	High	The handling of user data, digital transactions, and cultural or commercial content introduces moderate risks requiring robust data protection, encryption, and regulatory compliance to prevent misuse or breaches.
Financial/ operational	Low	Medium	High	Initial platform investment, ongoing technical maintenance, and ensuring equitable access present moderate operational and financial risks, particularly during scaling or when reaching underserved communities.

Implemented in:

Global SITE Network (including examples such as New York and Eilean Donan Castle, located near the Isle of Skye)

Case study: SITE network

While this is a Horizon 3 Use Case, the SITE network highlights the potential opportunities for this use case if built upon and expanded.

Context

The Social Interactive Twin Economy (SITE) network is a global collection of interoperable metaverse worlds offering immersive experiences in travel and commerce. Each virtual world represents a location, allowing local communities and cities worldwide to digitally showcase and monetize their assets, services and uniqueness. One such location to test was Eilean Donan Castle, located near the Isle of Skye, is one of Scotland's most iconic landmarks, attracting more than 540 000 visitors annually. Despite its popularity, the surrounding areas often remain overlooked by tourists. Visitors typically spend minimal time and money in the vicinity, leading to limited economic benefits for nearby communities. Additionally, many tourists lack knowledge about the region's rich history and cultural significance, resulting in a superficial experience and low return visitation rates.

Objective

To enhance visitor engagement, distribute tourism more evenly across the region, and bolster the local economy by:

- Providing immersive educational experiences that deepen understanding of the area's history and culture.
- Encouraging tourists to explore lesser-known nearby attractions.
- Empowering local communities to participate actively in tourism through digital platforms.

Solution approach

SITEnetwork's Minimum Viable Product (MVP) in the Eilean Donan area, focusing on:

- Developing VR and AR experiences that showcase the castle's history and nearby attractions.
- Creating a digital platform where local businesses and artisans can present their products and services to a global audience.
- Offering educational content co-created with local historians and community members to ensure authenticity.
- Digital twin Creation: Develop a high-fidelity digital replica of Eilean Donan Castle and its surroundings, accessible via VR headsets and mobile devices.
- Community Workshops: Conduct training sessions for local residents on creating and managing digital content, enabling them to contribute stories, historical insights, and information about local businesses.
- Interactive AR Trails: Design AR-guided tours that lead visitors to nearby points of interest, providing historical context and promoting local establishments.
- E-Commerce Integration: Establish an online marketplace within the platform, allowing tourists to purchase local products during and after their visit.

(continued)

Case study: SITE network

Results

The SITE network expects the following results:

- Increased visitor engagement & tourism diversification: Tourists spend more time exploring virtually and physically, deepening appreciation of cultural heritage. Virtual experiences draw attention to lesser-known sites, helping distribute visitor flows more evenly and alleviating over-tourism at hotspots.
- Economic growth & SME development: Local businesses benefit from increased physical and virtual sales through SITE's global reach and online marketplace. The platform enables new revenue streams for SMEs (e.g., tokenized souvenirs, digital merchandise, memberships), driving sustained economic activity and resilience during tourism downturns.
- Community empowerment & skills development: Residents participate in content creation, digital twin management, and e-commerce, gaining valuable digital skills and ownership over local narratives. Training and workshops foster ongoing community stewardship and pride.
- Employment opportunities: The hybrid economy model stimulates job creation and upskilling in emerging fields such as VR/AR development, blockchain, digital marketing and content management.
- Educational impact: Collaboration with educational and research institutions delivers immersive learning, integrating local history, culture, and sustainable practices into globally accessible curricula.
- Global access & market expansion: SITE opens new tourism and commerce opportunities for people facing mobility or geopolitical barriers, expanding economic benefits to underserved markets and ensuring local products reach an international audience – even following a physical visit.
- Environmental sustainability: By substituting some physical travel with high-quality virtual experiences and managing visitor demand through digital channels, SITE reduces tourism-related carbon emissions, supports biodiversity, and leverages blockchain for transparent, sustainable resource management.
- Resilience & innovation: The hybrid approach protects local economies from geopolitical or environmental disruptions and aligns with macro trends such as digital transformation, inclusivity, and sustainable development.

Lessons learned

- **Authenticity is key:** Involving local communities in content creation ensures that the narratives presented are genuine and resonate with residents and visitors alike.
- **Technology adoption requires support:** Continuous training and support are essential to help locals adapt to new digital tools.
- **Integrated experiences enhance value:** Combining educational content with commerce opportunities provides a holistic experience that benefits all stakeholders.

Conclusion

Deploying SITEnetwork's MVP in the Eilean Donan area presents a strategic opportunity to enrich tourist experiences, stimulate the local economy, and preserve cultural heritage. By leveraging immersive technologies and community collaboration, the initiative aims to transform the region into a model for sustainable and inclusive tourism.

Use case 6: Immersive interactive tourism (Horizon 1)

Description

Virtual world technologies can be used to reduce the negative impact of tourism on the environment and on the economy such as seasonal unemployment, dependency and overcrowding. From making available city/region multilingual XR guide systems, to virtual tours around the city, to having immersive interactive multisensory sites, metaverse allows users to experience all events and places anytime from anywhere. Tourism stakeholders can provide personalized exploration of cultural and historical content, offer more inclusive city visit options, have visitors immerse in a storytelling experience with different perspectives, without affecting the value of the experience, easily tailoring and customizing experiences to visitor´s preferences.

Impacts

1) **Quality education:** Immersive exhibits deliver contextualized historical and cultural content, deepening learning outcomes.
2) **Quality of life:** Access to virtual tourism reduces overcrowding, preserves urban livability, and provides inclusive experiences for those unable to travel.
3) **Tourism development:** Offers new engagement channels that extend a destination's reach, build off-peak visitation, and diversify offerings.
4) **Local economic growth:** Drives revenue on site and online through virtual tickets, digital souvenirs, and extended e-commerce – supporting SMEs and regional suppliers.
5) **Citizen engagement:** Empowers communities to co-create content, share local narratives, and participate in heritage preservation.

Key beneficiaries

- Tourists
- Museums
- Attraction guides
- Hotels and local businesses
- Local governments

Key technologies

- **Digital twins** – Real-time, dynamic 3D replicas of physical sites (e.g., city districts or heritage landmarks) enabling continuous updates and remote management.
- **Metaverse platforms** – Interoperable virtual worlds that host immersive experiences, social interactions, and commerce across multiple destinations.
- **AR** – Overlays of digital content onto the physical environment via smartphones, tablets, or AR glasses to enhance on-site navigation, historic reconstructions, and contextual storytelling.
- **VR**– Fully immersive simulations accessed through head-mounted displays, allowing visitors to explore reconstructions and guided tours of cultural sites from anywhere.
- **GenAI** – AI systems that generate personalized narratives, procedural content, and multilingual tour scripts in real time to tailor the experience.
- **AI** – Machine learning for visitor-behaviour analytics, dynamic content recommendations, and automated moderation of user contributions.

SDG alignment

- **SDG 4: Target 4.7** Ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development, global citizenship, appreciation of cultural diversity, and culture's contribution to sustainable development.
- **SDG 8: Target 8.9** By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products.
- **SDG 11: Target 11.4** Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
- **SDG 12: Target 12.b** Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products.

Risk level

Table 6 Risk level: Immersive interactive tourism

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	There are limited risks to public safety associated with this use case; however, precautions always need to be taken from a health and safety perspective when using XR headsets. Attention should also be given to immersive environments to ensure safety for all participants.
Stakeholder acceptance	Low	Medium	High	Existing projects demonstrate high interest from tourists' operators, and cultural institutions.
Data privacy and security	Low	Medium	High	Collected data (usage patterns, preferences) are low-sensitivity; GDPR-compliant consent and anonymization measures suffice to mitigate risks
Financial/ operational	Low	Medium	High	Development and maintenance of XR platforms, holographic theatres, and AI systems entail moderate costs and require specialized skills and ongoing content updates.

Implemented in:

Tehran, Iran; Helsinki, Finland; Eilean Donan Castle, Scotland (UK); Quintana Roo, Mexico; Edinburgh, Scotland (UK); Turin, Italy

Case Study: Meeting Rembrandt

Context

Rembrandt van Rijn (1606–1669) is celebrated for transforming portraiture through his innovative use of light, texture and narrative depth. His 1642 masterpiece, *The Night Watch*, remains a focal point of the Rijksmuseum collection and attracts large crowds. Meeting Rembrandt places participants at the heart of pivotal moments in Rembrandt's career, granting access to his 17th-century Amsterdam residence and atelier. Through seamless integration of live-action performance and computer-generated environments, the application enables interaction with the artist and observation of his techniques during the creation of *The Night Watch*.

Developed by ForceField in partnership with the Rijksmuseum and Samsung Gear VR for the Oculus platform, the experience features a refined interface and a highly responsive navigational map. Designed for universal accessibility – with no additional sensors or controllers required – the seven-minute guided tour conveys the ambience of Amsterdam during the Dutch Golden Age, presenting historically accurate reconstructions of canal-side streets, original sketches and paintings, and narrated insights from Rembrandt himself. Despite its concise duration, the programme maintains exceptional visual fidelity and depth, fostering an immersive encounter with the master painter and his milieu.[7]

(continued)

Case Study: Meeting Rembrandt

Objective

- To transport users to the year 1642 and recreate the atmosphere of Amsterdam's Dutch Golden Age through a historically accurate virtual environment.
- To facilitate direct engagement with Rembrandt, enabling observation of his studio practice and creative process behind *The Night Watch*.
- To broaden access to Rembrandt's life and work by offering a controller-free, seven-minute VR experience compatible with Samsung Gear VR headsets.
- To mitigate physical overcrowding in the Rijksmuseum by providing an immersive alternative that complements the in-person presentation of Rembrandt's masterpieces.[8]

Solution approach

Meeting Rembrandt: Master of Reality was produced by ForceField in collaboration with the Rijksmuseum and Samsung Gear VR as part of Oculus VR Experiences. Its core components comprised:

- Historical Reconstruction: Photorealistic 3D models of 17th-century Amsterdam, including Rembrandt's home and studio, were created using Rijksmuseum archival research. The Night Watch was digitized to capture paint layering and aged varnish.
- Live-Action Integration: Performance capture of actor Reinout Bussemaker as Rembrandt was filmed against green screen and seamlessly composited into the virtual setting for dynamic interaction.
- Interaction and Wayfinding: An in-scene 3D map and gaze-based controls guide users. Hotspots enable inspection of canvas layers, handling of period pigments, and activation of narrative segments on technique and context.
- Narrative Design: A seven-minute linear storyline escorts users from present-day Amsterdam to 1642, culminating in a direct exchange with Rembrandt at work on The Night Watch. Optional panels provide deeper scholarly insights.[9]

Results

- Immersive Temporal Transport: Participants inhabit an authentically reconstructed 1642 Amsterdam, complete with historic canals, architecture, and the artist's atelier, creating a powerful sense of time travel
- Educational Appeal: The blend of interactive storytelling, authentic artifacts and guided commentary resonated across age groups, supporting intergenerational learning in art history.
- Free Global Distribution: Available at no cost on the Oculus Gear VR store, the application democratizes access to Rembrandt's world, extending the museum's reach beyond its physical location.[10]

(continued)

Case Study: Meeting Rembrandt

Lessons learned

Key lessons learned include:

Accessibility and user experience design:

- Controller-free interaction broadens accessibility by eliminating barriers for users of all skill levels.
- A concise seven-minute session balances immersive depth with user comfort, minimizing fatigue for VR novices.
- Allowing users to suspend and resume the experience at will enhances comfort and accommodates individual pacing preferences.

Technical innovation and quality:

- Combining live-action footage with computer-generated environments achieves exceptional realism on mobile VR platforms.
- Employing Rijksmuseum technical research and archival materials ensures historical authenticity in environmental and artwork reconstructions.
- Meticulous performance optimization is essential to maintain smooth visuals and comfortable frame rates on Gear VR hardware.

Cultural heritage applications:

- VR functions as spatial and temporal transport, immersing users in past environments and events.
- Free, globally distributed VR experiences enable museums to expand audience access beyond their physical premises.
- Collaborative partnerships – combining technical, curatorial, and platform expertise – are vital to achieving innovation and authenticity.[11]

Conclusion

Meeting Rembrandt: Master of Reality illustrates how immersive virtual world technologies can extend cultural access, reduce overtourism pressures and stabilize heritage-sector employment. By combining live-action performance, archival-quality 3D reconstruction and interactive wayfinding, the Rijksmuseum and Force Field have created a replicable model for heritage institutions worldwide. This initiative underscores VR's potential to preserve and democratize art history in a sustainable, engaging manner.

Use case 7: Digital twins for sustainable economic development (Horizon 2)

Description

What if we can make virtual actions have real-world impact? It´s exactly what digital twins can bring to the economy. By replicating the real world, both land and sea structures, metaverse can be used to simplify testing, execute simulations, play out risks and consequences proactively while analysing possible outcomes. City and business stakeholders can leverage these features in their decision-making processes scaling it up or down as they see fit before implementation and use it as a transparency tool.

As this technology can be accessible anywhere, anytime, on any device, it can serve as a gateway to the virtual world providing a simple and sustainable path to use reality based immersive

experiences. This enables user engagement in a highly personalized manner, materializing the transparency of policy making, providing opportunities for better informed choices and presenting the impacts of actions in the real world.

Impacts

1) **Improved decision making:** Madalia enables stakeholders to make informed, consequence aware decisions before embarking on real-world implementation.
2) **Sustainable planning:** Through scalable digital modelling of environments, Madalia supports long-term environmentally aware development that focuses on climate, infrastructure and community requirements.
3) **Cost savings:** Simulations reduce requirements for physical trials and early-stage investment which can help minimise errors and optimise before real-world launches.
4) **Education and awareness:** Digital twins and immersive learning experiences help users gain a better understanding of impacts to the environment, sustainability options and knock on effects of digital actions.
5) **Public engagement and accessibility:** Available anytime on any device, Madalia helps reduce friction points when it comes to participation, allowing communities to be more involved in planning processes and decision making when it comes to sustainability.

Key beneficiaries

- City planners/developers
- Environmental and sustainability experts
- Businesses
- Educators/Researchers
- Tourism and Cultural Heritage sectors

Key technologies

- **Fractal computing:** Advanced computation techniques underpinning highly scalable and detailed simulations, enabling models to represent complex, multiscalar environments efficiently.
- **XR:** Immersive technologies including virtual, augmented, and mixed reality that provide rich, interactive experiences for users exploring digital twin environments on any device.
- **AI:** AI algorithms analyse data, optimize simulations, predict outcomes, and provide personalized insights to support decision-making and scenario testing in digital twins.
- **Digital twins:** Dynamic, real-time digital replicas of physical land, sea, and infrastructure systems that facilitate monitoring, simulation, and planning with spatial and temporal accuracy.
- **Blockchain technology**: Distributed ledger systems offering secure, transparent management of data, transactions, and ownership rights within digital twin environments, supporting trust and participatory governance.

SDG alignment

- **SDG 4: Target 4.7** Ensure all learners acquire knowledge and skills needed to promote sustainable development through education for sustainable lifestyles, human rights, and cultural diversity.
- **SDG 11: Target 11.3** Enhance inclusive and sustainable urbanization and capacity for participatory, integrated planning and management of human settlements.
- **SDG 13: Target 13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.
- **SDG 14: Target 14.2** Sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, supporting climate change mitigation and adaptation.
- **SDG 17: Target 17.17** Encourage and promote effective public, public-private, and civil society partnerships to mobilize knowledge, expertise, and resources to support sustainable development.

Risk level

Table 7 Risk level: Digital twins for sustainable economic development

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The platform is an entirely digital environment posing no direct threat to infrastructure or public health.
Stakeholder acceptance	Low	Medium	High	Adoption by governments and communities may be hindered by varying levels of readiness.
Data privacy and security	Low	Medium	High	Technologies may require the collection of user data. While standard protections can be applied to data collection the risk of breaches is always moderate and requires continued compliance with regulations and cybersecurity best practices.
Financial/ operational	Low	Medium	High	Some of the technologies used is advanced and can sometimes be costly to scale and maintain. However, with government support and industry/commercial partnerships the mitigation of long term financial and delivery risks are only moderate.

Implemented in:

Madeira Island

Case study Madalia Digital Twin for Sustainable Economic Development, Madeira

Context

The rapid digitalization of society has led to an increasing contribution of digital infrastructures to global carbon emissions, creating a pressing need for comprehensive tools to measure, manage, and reduce their environmental impact. Digital technologies, while essential for innovation and connectivity, consume substantial energy and create significant carbon footprints, often with underappreciated consequences for climate change initiatives. Against this backdrop, the island of Madeira – known for its unique cultural heritage and ecological sensitivity – has become the focus of a pioneering initiative integrating cutting-edge digital technologies to advance sustainable development.

Madalia represents the world's first full-scale digital twin of Madeira Island and its surrounding undersea environment. Built upon a fractal computing platform, Madalia provides a highly scalable and immersive digital replica of the region designed as an entryway to the metaverse. This platform leverages a suite of advanced technologies including XR, AI, blockchain, digital twins, and spatial computing to support transparent, data-driven decision making aimed at sustainable economic and environmental outcomes.

(continued)

Case study Madalia Digital Twin for Sustainable Economic Development, Madeira

Accessible on any device, anytime and anywhere, Madalia marks a new standard in immersive digital experiences by enabling stakeholders – from local governments and businesses to global users – to explore, simulate, and understand the interconnected impacts of their choices on the environment and economy. It acts as a bridge between virtual actions and real-world consequences, facilitating engagement and accountability across sectors.[12]

Objective

Madalia aims to empower companies and individual users with detailed insights into the environmental footprint generated by their digital activities. Specifically, it seeks to:

- Provide an accurate and dynamic quantification of carbon emissions and resource use associated with digital presence and operations.
- Enable users to simulate and preview the ecological and social consequences of digital decisions within Madeira's complex physical and socio-economic system.
- Offer customizable, transparent options for users and organizations to offset their digital carbon footprints through support of tangible real-world projects such as education initiatives, carbon capture technologies, and scientific research.
- Foster a culture of responsible digital innovation by integrating sustainability principles directly into virtual platform designs.
- Create an open but secure ecosystem that aligns digital development with Madeira's broader environmental sustainability goals.[13]

Solution approach

The Madalia platform integrates three core technological pillars – fractal computing, blockchain, and spatial computing – to deliver a robust, immersive digital twin environment capable of real-time, highly detailed simulation and engagement:

- **Fractal computing:** This advanced computational method enables Madalia to efficiently handle the immense complexity and scale of Madeira's landmass and undersea structures. By modelling the island and its surroundings through recursive, scalable algorithms, the platform achieves remarkable precision across spatial scales, from regional topography to minute ecological details, while maintaining performance that supports real-time interaction.
- **Spatial computing and XR interfaces:** Users interact with Madalia through extended reality environments that provide richly layered, spatially accurate visuals of Madeira's terrain, underwater ecosystems, and built environments. XR technologies enable immersive walkthroughs, scenario testing, and data visualization, making abstract sustainability concepts tangible and understandable for diverse audiences.
- **Blockchain technology:** Serving as the backbone of data integrity and transparency, blockchain records all transactions and decisions made within the Madalia ecosystem. This ensures traceability, verifiability, and accountability of environmental impact calculations and offsetting actions. Moreover, blockchain supports decentralized governance mechanisms and incentivizes sustainable behaviour through tokenization and smart contracts.

Together, these elements enable Madalia to function not only as a visualization tool but also as a participatory platform for environmental management, policymaking, and commercial innovation. It empowers users by quantifying their digital environmental footprints and linking these to real-world sustainability investments, thus materializing digital sustainability protocols.[14]

(continued)

Case study Madalia Digital Twin for Sustainable Economic Development, Madeira

Results

Since its inception, Madalia has demonstrated significant impacts at multiple levels:

- **Environmental impact awareness:** Madalia enables clear quantification and transparent communication of carbon emissions and other environmental impacts tied to digital infrastructures and user behaviour. This visibility is critical in aligning digital development with Madeira's ecological conservation priorities.
- **Sustainable economic development:** By offering businesses an accessible platform to simulate and optimize their digital presence's sustainability, Madalia supports the reduction of costs associated with inefficiency and regulatory risks. Many local and international companies have begun integrating Madalia's impact assessments into their corporate sustainability strategies, fostering green innovation and resilience.
- **Carbon neutral digital experiences:** Through the platform's Impact Protocol, users and brands can offset their digital footprints by directly funding projects in carbon capture, educational outreach, and environmental research. This holistic approach has driven early adoption of carbon-neutral virtual shopping, AI training modules, and immersive interactions.
- **Community and public engagement:** Madalia's accessible, gamified interfaces have attracted broad user participation, ranging from policymakers and educators to consumers and creators. This inclusivity has catalysed a shared sense of responsibility and empowerment regarding digital sustainability challenges.[15]
- **Technological leadership:** Madalia has positioned Madeira as a global reference point for metaverse-enabled environmental governance, demonstrating the viability of fractal computing-powered digital twins combined with blockchain transparency.

Lessons learned

The development and deployment of Madalia have yielded important insights critical for future digital sustainability initiatives:

- **Sustainability by design:** Embedding environmental impact measurement and mitigation mechanisms into the core architecture of digital platforms increases effectiveness and user engagement, contrasting with retrofitted approaches that are often fragmented.
- **Transparency fosters trust and action**: The use of blockchain for immutable, verifiable impact records has been essential in building stakeholder confidence and motivating behavioural change.
- **Multidisciplinary collaboration is key:** Achieving technical innovation that aligns with environmental goals requires collaboration across computing experts, ecologists, policymakers, and community representatives.
- **User Empowerment through gamification:** Making sustainability actions accessible, transparent, and rewarding encourages wider participation and reinforces positive digital behaviours.
- **Scalability requires robust architecture:** Fractal computing offers a promising path to scale complex digital twins without compromising performance or detail, making extensive metaverse applications feasible.

(continued)

Case study Madalia Digital Twin for Sustainable Economic Development, Madeira

Conclusion

Madalia exemplifies the powerful role that advanced digital twin platforms can play in addressing the environmental challenges posed by our expanding digital footprint. By combining immersive spatial computing, fractal algorithmic modelling, and blockchain-driven transparency, Madalia transforms the abstract notion of digital carbon emissions into actionable insights, accessible to all stakeholders. This inclusive approach not only supports Madeira's sustainable development but also provides a replicable model for integrating responsible innovation into the metaverse era. As the digital and physical worlds continue to intertwine, Madalia sets a precedent for how virtual actions can yield tangible, positive real-world impact.

Use case 8: Educational gaming for sustainability (Horizon 2)

Description

Achieving a sustainable balance between economic growth, environmental stewardship, and social equity for future generations necessitates innovative approaches in education. This involves developing new tools and reshaping learning frameworks to emphasize sustainability. Educational gaming, powered by Web3 and immersive technologies, offers a unique fusion of purposeful digital play and interactive learning. By embedding rules that address environmental and resource management challenges, such gaming platforms provide dynamic, interactive, and effective sustainability education. This approach cultivates awareness and knowledge in younger generations, encouraging responsible behaviours from an early age.

Impacts

1) **Environmental awareness:** Interactive digital play fosters early understanding of the delicate relationship between economic development and environmental conservation.
2) **Marine and ecosystem conservation education:** Virtual exploration and data-driven content enhance comprehension of ecosystem dynamics and conservation necessity.
3) **Climate action motivation:** Game scenarios encourage players to identify and respond to climate threats affecting natural habitats.
4) **Youth engagement and empowerment:** Gamified learning resonates with digitally native generations, motivating active participation in sustainability advocacy.
5) **Biodiversity preservation awareness:** Accurate ecosystem representations highlight the importance of protecting diverse species and habitats.
6) **Effective gamified education**: Complex ecological and sustainability concepts are made accessible and engaging through gameplay mechanics.

Key beneficiaries

- Younger generation/students
- Educators
- Sustainability and conservation organizations
- Policy makers and sustainability advocates

Key technologies

- **Web3:** Decentralized technologies enabling transparent, secure governance and incentivization within educational gaming ecosystems.
- **Blockchain:** Immutable record-keeping and tokenization systems that support accountability, reward mechanisms, and data security in gamified learning platforms.
- **Immersive gaming engines** (e.g., Unreal Engine): Providing rich, 3D simulated environments that realistically engage users and enhance learning through exploration and interaction.
- **Scientific data integration**: Incorporation of credible environmental data from research institutions to ground gameplay in authentic sustainability contexts.

SDG alignment

- **SDG 4: Target 4.7:** By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.
- **SDG 13: Target 13.3:** Improve education and awareness for climate change mitigation, adaptation, impact reduction, and early warning.

- **SDG 14: Target 14.2:** By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.

Risk level

Table 8 Risk level: Educational gaming for sustainability

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The platform operates in a digital environment and poses limited risks to the public.
Stakeholder acceptance	Low	Medium	High	The risk of stakeholder acceptance is low due to alignment of the project to global sustainability goals. Support from educators, community groups, and environmental experts will support stakeholder acceptance
Data privacy and security	Low	Medium	High	Technologies may require the collection of user data. While standard protections can be applied to data collection the risk of breaches is always moderate and requires continued compliance with regulations and cybersecurity best practices.
Financial/ operational	Low	Medium	High	Some of the technologies used is advanced and can sometimes be resource intensive which can be costly. Building and scaling a blockchain based platform while expanding a user base in space such as gaming can also contribute to moderate financial and operational risks.

Implemented in:

Siemens Decarbonisation Game Environment; Endless Ocean VR Experience; Novelab Environmental VR Games; Playing for the Planet Alliance

Case study: Scubaverse

Context

Marine ecosystems are facing unprecedented threats from climate change, pollution, overfishing, and habitat degradation. Coastal communities and island nations, in particular, bear the brunt of these impacts, underscoring an urgent need for public awareness and engagement in marine conservation efforts.

Traditional educational approaches often struggle to captivate digitally native younger generations, leaving a critical gap in sustainability literacy. Scubaverse addresses this gap by leveraging emerging technologies to create immersive, interactive educational experiences designed to foster environmental stewardship and advocacy among youth worldwide, with particular relevance for coastal cities that depend on healthy ocean ecosystems for economic and social well-being.

(continued)

Case study: Scubaverse

Objective

Scubaverse aims to inspire and educate younger generations about marine conservation, climate action, and biodiversity through gamified learning. By integrating environmental advocacy directly into engaging gameplay, the platform seeks to:

- Build early awareness of ocean health challenges and the delicate balance between economic development and environmental preservation.
- Provide interactive, data-driven simulations that allow players to explore realistic marine ecosystems and witness the consequences of human activities on aquatic life.
- Empower youth to become active participants in environmental advocacy by translating virtual actions into real-world impact.
- Support coastal city stakeholders – educators, policymakers, and conservation organizations – in fostering community engagement and sustainability education.

Solution approach

Scubaverse combines a suite of advanced technologies and scientific partnerships to deliver a compelling educational gaming experience:

- **Web3 and blockchain integration:** Utilizing decentralized ledgers, the platform ensures transparent tracking of in-game contributions to real-world conservation projects. Tokenized incentives reward players for sustainable virtual behaviours such as habitat restoration and pollution clean-up simulations.
- **Unreal engine–powered immersive environments:** High-fidelity 3D ecosystems, built with Unreal Engine, recreate coral reefs, kelp forests, and open-ocean habitats. Realistic marine species behaviour and underwater physics provide a visceral sense of exploration and discovery.
- **Gamified learning mechanics:** Interactive missions such as deploying virtual reef restoration units or monitoring ship-based pollution events, immerse players in scenario-based learning. Progression systems, leaderboards, and community challenges drive engagement and reinforce positive environmental actions.
- **Accessible cross-platform delivery:** Scubaverse is available as a mobile application and a web-based portal, requiring only standard smartphones or tablets. No specialized VR hardware is necessary, maximizing accessibility for diverse socio-economic contexts, particularly in coastal cities.

(continued)

Case study: Scubaverse

Results

Scubaverse delivers accessible, immersive educational content that helps young learners deepen their awareness of global climate and conservation issues through engaging gameplay. By navigating virtual reefs, monitoring simulated water quality, and responding to ecosystem challenges, students gain first-hand insights into the complexity of marine environments. This experiential learning approach fosters systems thinking learners begin to recognize how individual actions – such as overfishing, pollution, or habitat restoration – ripple through food webs and influence ocean health.

Moreover, the platform's interactive missions encourage critical inquiry and problem-solving. As players troubleshoot virtual oil spills, design sustainable aquaculture systems, or plan coral transplant operations, they practice decision-making skills rooted in scientific reasoning. These exercises build confidence and agency, empowering learners to draw parallels between game scenarios and real-world environmental management.

Teachers integrating Scubaverse into their curricula report that the gamified format sparks curiosity and sustained interest in STEM and environmental subjects. Rather than passively absorbing information, students actively construct knowledge by hypothesizing outcomes, testing strategies, and reflecting on ecological trade-offs. This participatory model enhances retention of key concepts – such as carbon sequestration, species interdependence, and the impacts of climate change – compared to traditional lecture-based instruction.

Finally, Scubaverse's digital-first design supports equitable access to high-quality sustainability education. Schools and community organizations can deploy the platform on existing devices without requiring specialized equipment, ensuring that a diverse range of learners – including those in under-resourced coastal regions – can benefit from immersive environmental learning. In doing so, Scubaverse lays the foundation for a generation of informed, digitally literate advocates ready to engage in real-world conservation efforts.

Lessons learned

Key Lessons learned include:

- **Authentic data drives credibility:** Integrating real scientific datasets was essential to establishing Scubaverse as a trusted educational tool and to maintaining long-term stakeholder partnerships.
- **Accessibility maximizes impact:** Cross-platform availability without VR hardware requirements enabled broad participation, particularly in under-resourced coastal communities.
- **Gamification sustains engagement**: Reward systems and community challenges proved effective at motivating sustained player involvement and reinforcing collective action towards conservation goals.
- **Localized content enhances relevance:** Tailoring scenarios to regional environmental issues – for example, coral bleaching in Australia versus plastic pollution in South Africa – boosted learner empathy and contextual understanding.
- **Measurable outcomes foster support**: Tracking knowledge gains and virtual-to-real-world action metrics provided concrete evidence of impact, facilitating further funding and educational adoption.

(continued)

Case study: Scubaverse

Conclusion

Scubaverse demonstrates the transformative potential of combining Web3, immersive gaming, and scientific collaboration to advance marine conservation education. By creating authentic, engaging virtual ocean ecosystems, the platform empowers youth – especially in coastal cities – to become informed advocates for sustainability. Scubaverse's scalable, accessible design and measurable educational outcomes offer a replicable model for leveraging digital innovation to address global environmental challenges. As marine ecosystems continue to face intensifying threats, such immersive educational gaming initiatives will be critical in cultivating the next generation of conservation leaders and ensuring the long-term health of our oceans.

Use case 9: Virtual entertainment (Horizon 2)

Description

Large scale, immersive digital experiences for audience-driven events powered by spatial computing, generative AI, and XR technologies are transforming the way audiences attend and engage with live events. Covering different types of events from football matches to concerts, festivals or even motorsport races, virtual arenas and custom skybox lounges will bring live streamed experiences to fans, as well as the opportunity to interact with fellow enthusiasts and the chance to enjoy one-on-one video chats with their idols anywhere in the world. Additionally, enthusiasts can immerse in event merchandising retail experiences and access Hall of Fame information about the event. These virtual live event experiences offer new levels of accessibility and inclusivity, fostering innovative ways of utilizing existing city infrastructures, growing marketing opportunities, building new revenue streams and focus on intellectual and nonmaterial property ownership protection and management.

Impacts

1) **Accessibility**: The creation of immersive digital arenas helps eliminate barriers such as cost for audiences and geographical location in relation to events. Global audiences can now experience live events in an inclusive and affordable way.
2) **Citizen engagement:** Enabling interactive feature such as real time chat and one-on-one video sessions with athletes or performers creates a deeper community connection in cultural moments.
3) **Sustainable attendance:** Enabling the inclusion of a potentially global audience in live events while eliminating the requirement for travel allows for the reduction of environmental impacts caused by attendance while at the same time expanding reach and inclusivity.
4) **Quality of life:** High quality entertainment and social experiences made more accessible through virtual access of live sports and concerts will help enhance individual wellbeing.
5) **Local economic development:** Virtual arenas could help unlock new economic opportunities in the forms of virtual merchandising, digitisation of event services and increased brand awareness while enabling cities and event organizers to participate in revenue generation beyond physical venue limitations.

6) **Cultural participation:** Cultural and entertainment experiences that bolster inclusivity and community identity can become more broadly engaged with by broader audiences due to these immersive technologies.

Key beneficiaries

- Fans and enthusiasts
- Event organizers
- People with mobility limitations/geographical limitations
- Digital experience developers/designers
- Government and smart cities

Key technologies

- **Spatial computing**: can creates large-scale virtual venues by integrating geospatial data and real-time tracking, enabling users to navigate digital stadiums and festival grounds as if physically present. Geo-fenced interactive zones within these spaces deliver targeted content – such as VIP lounges or merchandise kiosks – enhancing personalized engagement.
- **AI:** AI personalizes live event experiences by analysing user interactions to produce adaptive highlight reels, commentary, and visual effects in real time. AI-driven virtual hosts and chatbots facilitate one-on-one conversations, recommend sessions, and moderate discussions to ensure that each attendee's journey is tailored uniquely.
- **VR/AR:** XR technologies transport audiences into fully digital arenas or overlay immersive 3D graphics onto physical venues, allowing fans to interact with avatars of performers and athletes. Whether via VR headsets for remote access or AR-enhanced in-person experiences, these tools expand accessibility and blur the lines between real and virtual attendance.
- **Streaming video technologies:** Adaptive streaming protocols and edge computing deliver synchronized, low-latency HD video feeds of live events into virtual arenas, ensuring smooth playback across diverse network conditions. Integrated spatial audio and interactive overlays – like multiangle camera switching and in-stream commerce – create an engaging, cinema-quality experience for all viewers.

SDG alignment

- **SDG 8: Target 8.2** Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high value added and labour-intensive sectors.
- **SDG 11: Target 11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities.

Risk level

Table 9 Risk level: Virtual entertainment

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	The use case is a virtual experience which poses limited threat to safety.
Stakeholder acceptance	Low	Medium	High	The risk of stakeholder acceptance is low due to the many potential benefits across many different stakeholders such as accessibility, inclusivity, affordability for audiences, as well as the elimination of limiting factors such as geography and cost for audiences. Additionally, possibilities for expansion of existing revenues and creation of new ones such as virtual stores also represents a solid commercial opportunity also.
Data privacy and security	Low	Medium	High	Technologies may require the collection of user data. While standard protections can be applied to data collection the risk of breaches is always moderate and requires continued compliance with regulations and cybersecurity best practices.
Financial/ operational	Low	Medium	High	Dependence on technologies such as cloud hosting, live streaming and XR infrastructure can be costly. Compared to physical infrastructure the costs of development, execution and maintenance are lower but still represent a moderate financial and operation requirement.

Implemented in:

Coachella, California; Fortnite and Roblox hosting virtual concerts; metaverse Fashion Week by Decentraland; The Fabric of Reality, London; Mercedes Benz Stadium, Atlanta

Case study: FIM Speedway Grand Prix

Context

The FIM Speedway Grand Prix is a premier international motorsport series attracting passionate fans to high-speed motorcycle competitions in stadiums across Europe. Traditional venue constraints – limited seating, geographic barriers, and high travel costs – impeded equitable fan access and restricted sponsor exposure to local audiences. In its centennial season, FIM Speedway partnered with infinite reality to pilot the world's first immersive metaverse experience, leveraging spatial computing, AI, XR, and streaming technologies.

The initiative aimed to transform local speedway races into globally accessible digital events, expanding fan engagement and opening new revenue streams for organizers, teams, and host cities.[16]

Objective

The virtual worlds adaptation of FIM Speedway Grand Prix sought to:

- Remove geographic and financial barriers to event attendance by offering virtual access to live races.
- Enhance fan engagement through interactive features – multiangle camera selection, rider meet-and-greets, and personalized commentary.
- Generate new revenue streams via digital merchandising and premium virtual skybox experiences.
- Provide deeper data ownership and analytics for event organizers, improving sponsorship value and marketing insight.
- Demonstrate the viability of digital first strategies in augmenting physical motorsport events with immersive technologies.[17]

Solution approach

In its role as the global promoter of FIM Speedway, the events arm of Warner Bros. Discovery Sports Europe has partnered with Infinite Reality to explore innovative avenues for interactive fan engagement utilizing Web3 technologies. By introducing a preview of its immersive speedway environment during the season, FIM Speedway extends and enhances its traditional in-stadium experiences – offering longstanding and new fans worldwide greater opportunities for connection and participation, regardless of location. Key components included:

- Pioneering Partnership: FIM Speedway GP and Infinite Reality teamed up to launch the world's first fully immersive, socially interactive speedway experience.
- Accessible iOS Platform: The FIM SGP-VERSE app is now free to download for iOS users, making state-of-the-art event engagement widely accessible.
- Multitouchpoint Fan Interaction: The app delivers a comprehensive experience, offering a mix of custom camera options, exclusive pit reporter feeds, and extensive on-demand video content.
- Unique Meet-and-Greet Opportunities: Fans can virtually interact with major international speedway stars – including Jack Holder, Tai Woffinden, Leon Madsen, and reigning world champion Bartosz Zmarzlik – before each race.
- Social Immersion via Avatar Chat: Features like Overhead Video and Audio Chat using avatars provide fans with enhanced social connectivity inside the digital arena.

(continued)

Case study: FIM Speedway Grand Prix

- Dynamic Camera Controls: Users are empowered to toggle between first-person and third-person perspectives, giving them control over how they view the action.
- Customisable Viewing Experience: The platform offers flexible video feed choices such as a dedicated trackside camera, so users can direct their own event coverage.
- Instant Map Teleportation: Quick-travel features let users instantly explore different virtual spaces and areas of the speedway environment.
- User-Friendly Device Navigation: Designed for ease of use, the app supports keyboard controls and touchscreen input, making navigation seamless across various devices.[18]

Results

The VR platform was piloted to a test group via laptop and desktop computers, in advance of the public launch of the mobile application. Research undertaken found that 96 per cent of the attendees found the experience to be innovative, 98 per cent found the track view showcased in the Skybox appealing, while 96 per cent liked the Meet and Greet with future riders. The research also found that average users stayed in the immersive experience for 138 minutes.

"The preview of the FIM Speedway metaverse experience has been an opportunity to test how fans can engage with their sport in new ways, as well as open a window into opportunities to attract new and different fans to speedway in the future. The preview provides innovative ways to explore the world around the live race action that fans currently enjoy, showing how fans in the future can enter an exciting experience that allows them to fully-immerse themselves in the sport during and between races." Jean Baptiste Ley, Motorsport Series Leaser at Warner Bros. Discovery Sports Europe.[19]

Lessons learned

- **Hybrid, virtual and mixed reality for events:** Digital strategies can unlock unrealised value in audiences while producing an enhanced version of the live event experience.
- **Prototype to production evolution:** The browser-based preview provided valuable user feedback leading to interface refinements, mobile app feature prioritization, and latency optimizations ahead of the full launch.
- **AI Hosts:** Piloting a generative AI host provided real time information and insights about the speedway experience and supported deeper exploration and easier navigation.
- **A host of innovations was key to success:** From virtual skyboxes, to meet and greets and content zones, the wide variety of activities and areas to explore enabled the success of the initiative and a high average time of engagment from participants.

Conclusion

By pioneering immersive metaverse experiences for the FIM Speedway Grand Prix, Infinite Reality and FIM Speedway have demonstrated how digital entertainment revenue models can coexist with, and enhance, traditional live events. Spatial computing, AI personalization, XR overlays, and seamless streaming technologies collectively removed attendance barriers, amplified sponsor value, and unlocked significant new revenue channels – all while reducing environmental impact. This digital-first strategy not only broadened fan engagement globally but also provided a scalable framework for other sports and entertainment organizations seeking to innovate and diversify in the rapidly evolving digital era.

Use case 10: Metaverse marketplace (Horizon 3)

Description

Metaverse marketplaces can play a significant role in advancing circular economy and entrepreneurship in cities and communities, as well as supporting remote employment and promoting local business expansion. Interactive immersive environments for trade through virtual stores or offices, exhibition centres, learning booths or showrooms can be created with custom or ready-made content facilitating trade of products and services or setting up new businesses without the physical infrastructure nor the initial material and logistic costs. Sales processes can be simplified and exchanges facilitated, the re-utilization and tracking of virtual assets and services can incentive sustainable practices and second-hand sales, providing data in real time can re-educate consumers and stimulate direct consumer engagement with brands whilst exploring digital currency exchanges can open the way to the transformation of today´s finance system to a more equitable one.

Impacts

1) **Responsible consumption and production:** by providing transparency from production to consumption, tracking all the process, it can create awareness and incentive more responsible consumption and production.
2) **Decent work and economic growth:** being online without the initial costs of setting up business, promoting inclusive economic growth focuses on creating opportunities for everyone to have access to quality employment and safe working conditions.
3) **Gender equality:** online opportunities regardless of gender.
4) **Reduced inequalities**: being online, focuses on creating opportunities for everyone to have access to quality employment and entrepreneurship.
5) **Partnerships for the Goals**: Being a marketplace online, it will enhance partnerships and collaborations of complementary goods and services.

Key beneficiaries

- Local business
- Entrepreneurs
- Consumers

Key technologies

- **Metaverse:** Decentralized virtual environments enabling businesses to establish digital storefronts, showrooms, and interactive marketplaces without physical infrastructure, reducing startup costs and geographical barriers.
- **AR:** Overlay digital product information, virtual try-ons, and spatial placement visualization in real-world environments, enhancing customer experience and reducing return rates through better purchase decisions.
- **VR:** Immersive 3D environments allowing customers to navigate virtual stores, examine products in detail, and participate in interactive demonstrations from any location globally.
- **AI:** Powers personalized recommendations, automated customer service, virtual assistants, and predictive analytics for inventory management and consumer behaviour insights within virtual marketplaces.

SDG alignment

- **SDG 8: Target 8.2** Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value-added and labour-intensive sectors.
- **SDG 8: Target 8.3** Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services.
- **SDG 8: Target 8.4** Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead.
- **SDG12: Target 12.2** By 2030, achieve sustainable management and efficient use of natural resources.

Risk level

Table 10 Risk level: Metaverse marketplace

Risk attribute	Risk rating			Explanation
Public safety	Low	Medium	High	Virtual marketplace operations pose minimal direct physical safety risks to users, although counter measures need to be taken to avoid risks such as online abuse.
Stakeholder acceptance	Low	Medium	High	Mixed acceptance due to technological barriers, digital divide concerns, and resistance from traditional retailers, though early adopters show strong enthusiasm for innovative commerce models.
Data privacy and security	Low	Medium	High	Collection of user behaviour data, payment information, and personal preferences requires robust cybersecurity measures and compliance with evolving privacy regulations across jurisdictions.
Financial/ operational	Low	Medium	High	Significant investment required for platform development, maintenance, and scaling, with uncertain ROI timelines and dependency on emerging technology infrastructure that may face compatibility issues.

Implemented in:

N/A

Case study

For this use-case, no relevant case study has been identified due to the horizon 3 level.

About the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse*

Launched by ITU, UNICC, and Digital Dubai, the Global Initiative on Virtual Worlds and AI – *Discovering the Citiverse* is a multistakeholder platform dedicated to shaping the next generation of AI-powered virtual worlds[20].

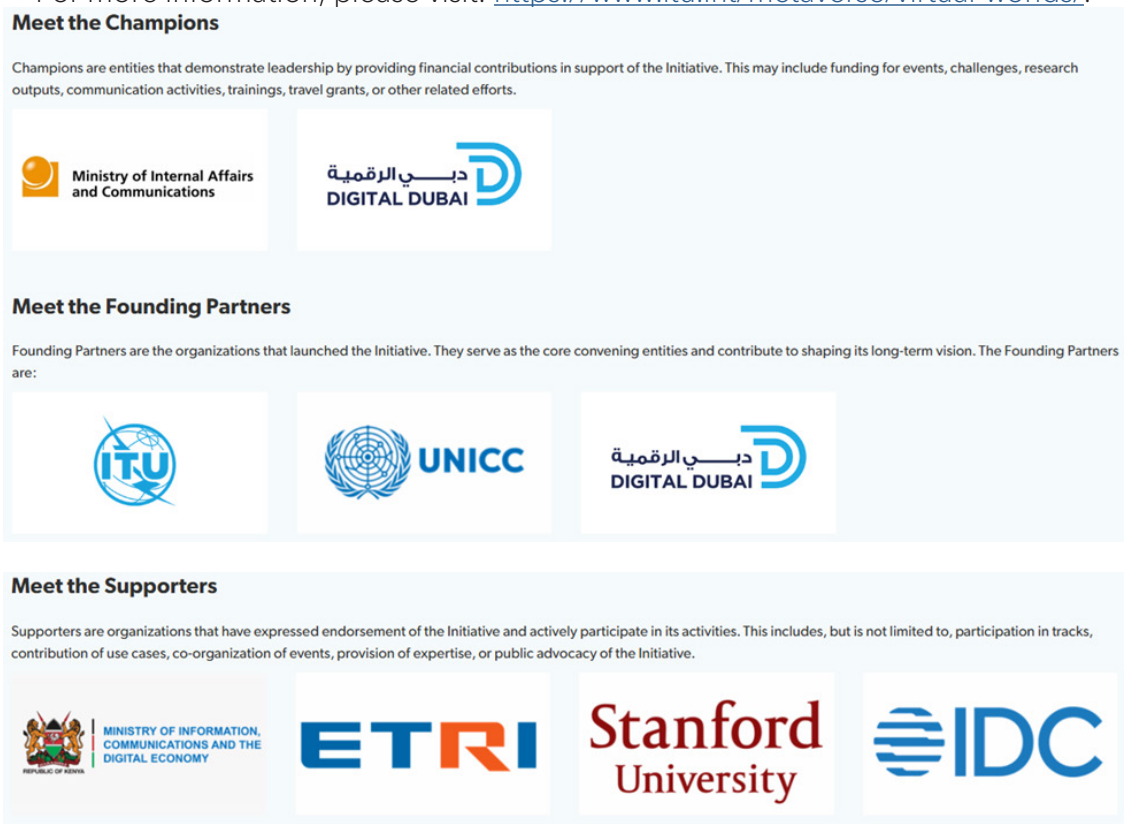
These immersive digital environments are transforming how people live, learn, govern, and interact. The Initiative ensures that AI-powered virtual worlds evolve in ways that are inclusive, interoperable, and human-centric—and that they help deliver on the Pact for the Future and its Global Digital Compact.

Serving as a neutral and action-oriented platform, the Initiative brings together cities, governments, UN agencies, private sector companies, academia, and civil society to collaboratively shape the responsible development and deployment of these technologies.

The Initiative advances its mission through three strategic pillars, each supported by dedicated tracks that address the most urgent challenges and promising opportunities in AI-powered virtual worlds. This comprehensive structure enables the Initiative to deliver both high-level global guidance and practical implementation in cities worldwide.

The Initiative is supported by over 70 international partners.

For more information, please visit: https://www.itu.int/metaverse/virtual-worlds/.

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