

PROJECT DETAILS

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1. EXECUTIVE SUMMARY

The Eden Universe Testbed commenced in November 2020 as part of the 5G Create Testbed and Trials programme and has run for the past seventeen months culminating in March 2022.

A consortium of four partners including Eden Project, aql, Marshmallow Laser Feast and Meta Camera came together to answer the question as to whether 5G technologies could enhance Eden's visitor journey onsite as well as online, and whether a digital offering could increase our audience reach. This was all to be delivered in line with Eden's mission of creating a movement that builds relationships between people and the natural world.

To achieve this the consortium deployed a series of use case trials utilising a 360° 5G non-standalone (NSA) shared spectrum network that used 5G techniques aiding the delivery of multiple unique experiences across a variety of digital technologies including a virtual tour, high resolution 360° cameras, augmented and virtual reality.

Supply chain issues and subsequent delays affected the delivery of the required data speeds to achieve the use case experiences defined at the start of the project. However, the consortium was able to deliver a range of high quality and unique end products that include the foundations of a network and infrastructure that will lend itself to new and exciting opportunities across multiple sectors for the future.

The project was able to cater for use case trial one, **VISITOR EXPERIENCE**, by deploying groundbreaking onsite experiences and an online virtual tour. An augmented reality VIP experience was developed between the creative minds of Eden Project's interpretation and storytelling team alongside Marshmallow Laser Feast, where visitors have been able to use devices to immerse themselves into the invisible worlds of our Rainforest Biome.

This was deployed in the form of "The Living Lens" AR experience, where visitors were able to experience the Rainforest environment as different animals such as mosquitos, bees and bats. The second utilisation of AR named "The Weather Maker", allowed guests to use the devices as a virtual X-ray viewing the interconnected systems that lay underground and contribute to the world's climate as we know it.

These experiences were then adapted for online viewing and contributed to the Eden Universe virtual tour which hosted an aerial 360° tour of the whole Eden Project site as well as live streams from multiple 360° cameras, guided tours and a data dashboard that utilises data from newly installed sensors to tell the story of Eden Projects plans to be climate positive by 2030.

The projects second use case trial catered for the **EDUCATIONAL** visitor – utilising the content and journey on the Eden Universe virtual tour and multiple curated educational packages for KS1 – 4 the team live streamed to over 1000 students at multiple schools from the rainforest biome, creating an engaging and thought-provoking lesson for those that participated – something that the Eden Project education team intend to roll out and develop over the coming months.

Our third use case saw the project deliver experiences in care homes across Cornwall and Liverpool as part of our research into **HEALTH & WELLBEING** and the technologies effects on this space.

Bespoke experiences that utilized different elements of the virtual tour such as the live at Eden camera streams and the curated Virtual Nature tours were made available to residents of separate

care homes on either iPad or through our “Room with a view” which included a large-scale projector screen and installation of plant life to enhance the offering.

In addition, the project also delivered bespoke VR experiences through Oculus Quest 2 headsets, this medium provided valuable feedback for future iterations with the focus of this aspect being on residents with dementia.

This use case trial also produced a collaboration between Eden Universe and Liverpool 5G which proved fruitful for all involved and provided the Universe with some extremely positive feedback and content for our Benefits Realisation documentation.

The Eden team embarked to Liverpool where we installed the Health & Wellbeing experiences at a Liverpool based 5G enhanced care home – the results conclusive told us that the content created very much indeed enhanced visitor experience, quality of life and increased the sample groups connection to nature and other people by providing a virtual trip to Eden for people who may never experience it in real life.

The final use case provided content for our **ART & CULTURE** deployment. As part of the project the consortium delivered Eden’s first ever live streamed wellness event, “Rainforest Reconnect”, directly from the Rainforest Biome at the Cornwall site through an event platform.

This performance included a wealth of content including a 5-track album of songs that were created utilising data from the plants within the biome itself and played under a 6-piece choir, as well as dancers, yoga, breathing exercises and additional wellbeing activities.

Lastly, as part of the project, the team at Eden and aql have installed and deployed a series of IoT sensors that will be utilized across all the entities teams to better understand its visitors and location. This data has been located to a data lake that will enhance the operations, overheads, sustainability and visitor experience not only for the Cornwall site but all New Edens.

Despite the issues deploying the initially proposed 5G network, the testbed has been deemed a great success and an incredible amount of work has been achieved within the short lifespan of the venture by all involved.

The Eden Project has legacy ambitions for all the content and technologies installed within its future offerings, and has now been encouraged to think differently as to how it tells its stories and spreads its mission.

A key takeaway has been that digital technologies, supported by the speeds availed by 5G networks, are imperative to these stories and messaging that Eden Project Cornwall and its wider sites are aiming to convey.

However, these technologies are more impactful when telling the story of our connection to nature and the planetary emergency when they are utilised alongside human delivery and interactions.

2. INTRODUCTION

The Eden Universe was born from an ambition to utilize 5G and digital technologies to deploy visitor enhancement solutions that cannot be delivered via existing networks.

Our aim was to bring together a consortium of four partners with different skillsets to enhance the visitor experience both onsite and online, while at the same time increasing our audiences, by accelerating and demonstrating the deployment of multiple experiences that sat within four different exemplars.

- Visitor Experience
- Educational
- Health & Wellbeing
- Art & Culture

This approach to Eden Project's offering was intended to show how to create competitive advantage for experience-based UK companies in a tough global market mid/post pandemic.

The overall project delivery aim was to harness the high channel bandwidth, edge offload and low latency capabilities of 5G networks for the cost-effective, sustainable delivery of solutions that enhance the visitor experience and management at the Eden Project site in Bodelva, Cornwall, and at other visitor attractions.

It was planned to enable partners to test efficacy, sustainability, and commercial viability of 3 key issues:

1. The use of 5G to enhance the onsite visitor experience.
2. Delivery of tailored, remote Eden experiences
3. Their use at other similar visitor attractions in the UK and internationally (including other Eden sites, the ASDC network of over 60 Science Centres across the UK engaging with 20 million visitors per year, the Botanical Garden's network and other arts institutions etc).

The four partners that worked on the project were:

- **Eden Project.** One of the UK's most popular contemporary environmental charities.
- **aql.** One of the UK's most innovative telecoms and 5G mobile network operators.
- **MLF.** Marshmallow Laser Feast - one of the world's leading immersive media studios.
- **META.** Pioneers in Immersive Cameras and Technology.

Key project deliverables included:

1. An evolving 5G NSA-SA mobile network installed at the Eden Project.
2. KPIs/metrics to enable the assessment of 5G enabled solutions for visitor attractions.
3. Integration of this 5G network with sensors, 360° cameras and existing systems to create a Proof-Of-Concept platform for visitor experience and site management solutions.
4. Specific digital content developed for use with visitor experiences.
5. Visitor enhancement/content delivery solutions (e.g. augmented reality on-site and remote) developed, deployed on-site measurable against pre-defined KPIs/metrics.
6. Management improvement solutions developed, deployed on-site, and assessed against pre-defined KPIs/metrics.
7. Report of the benefits/challenges of 5G to support an enhanced visitor experience (at the Eden Project and other attractions)

3.1 DESCRIPTION OF TESTBED – DEPLOYMENT OF USE CASES

The Eden Universe successfully deployed all four of its use cases exemplars digitally and in person, the following provides an overview of these deployments.

USE CASE ONE: VISITOR EXPERIENCE

Visitor Experience - Online

The experience for visitors online has been accessed through the Eden Universe platform. Upon receiving a tailored link to said platform, our visitor groups were guided to select either the 'Virtual Tour' or the 'Invisible Rainforest', depending on which part of the evaluation they agreed to take part in.

Virtual Tour: Deployment of Eden narrative mapped to site

Main Experience

Once members of our sample group selected 'Virtual Tour' they landed on an aerial view of the Eden Project (EP) site and were able to navigate the different areas in their own time.

From the aerial map, the tour features the four main areas of the site, indicated by the yellow icons:

- Outdoor Garden
- Rainforest Biome
- Mediterranean Biome
- Core

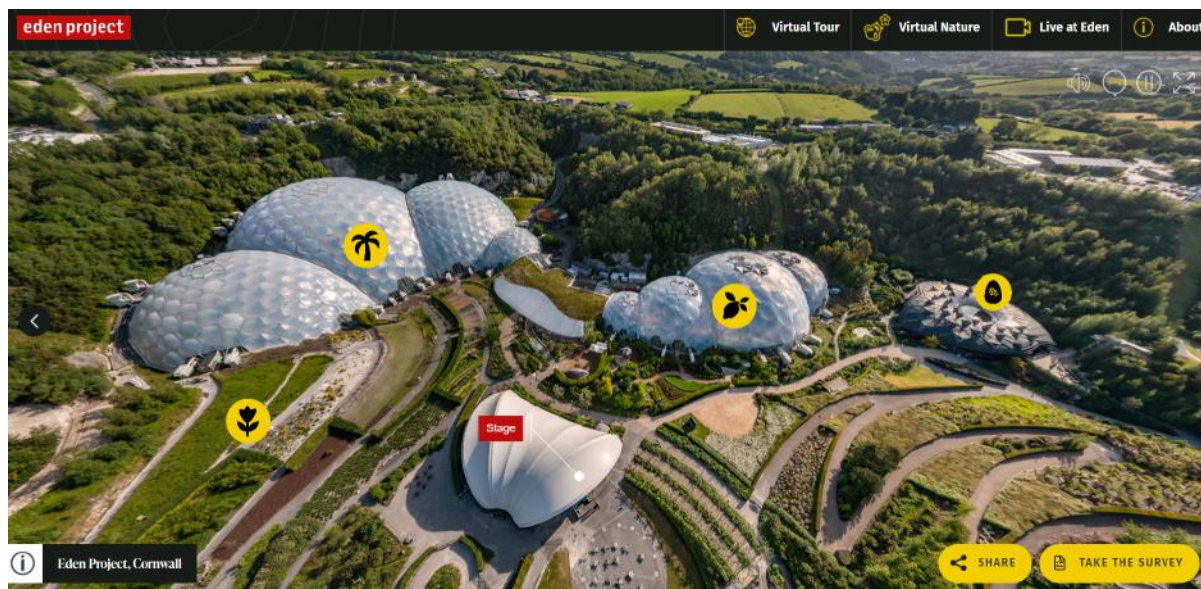


Image 1: Virtual tour overview screenshot

There was an introductory video that included an informative welcome video from either our Assistant Content Curator or our Biomes Manager when you first enter a new area on the platform.

From here visitors were able to select whether they'd like to explore that area from the aerial view, or they can click 'views' to access a side menu with information on each area and the views available.

Here our sample group were able to access the live META camera feeds that are accessed via embedded YouTube live streams and through the Live at Eden section.

Any video that is not able to be live for any reason, will play a pre-recorded version from that area. The live stream videos have pre-recorded ambient sound, for the privacy of any visitors that can be seen from the cameras. EP has updated its entry terms and conditions to inform visitors that we have live streaming cameras in certain locations.

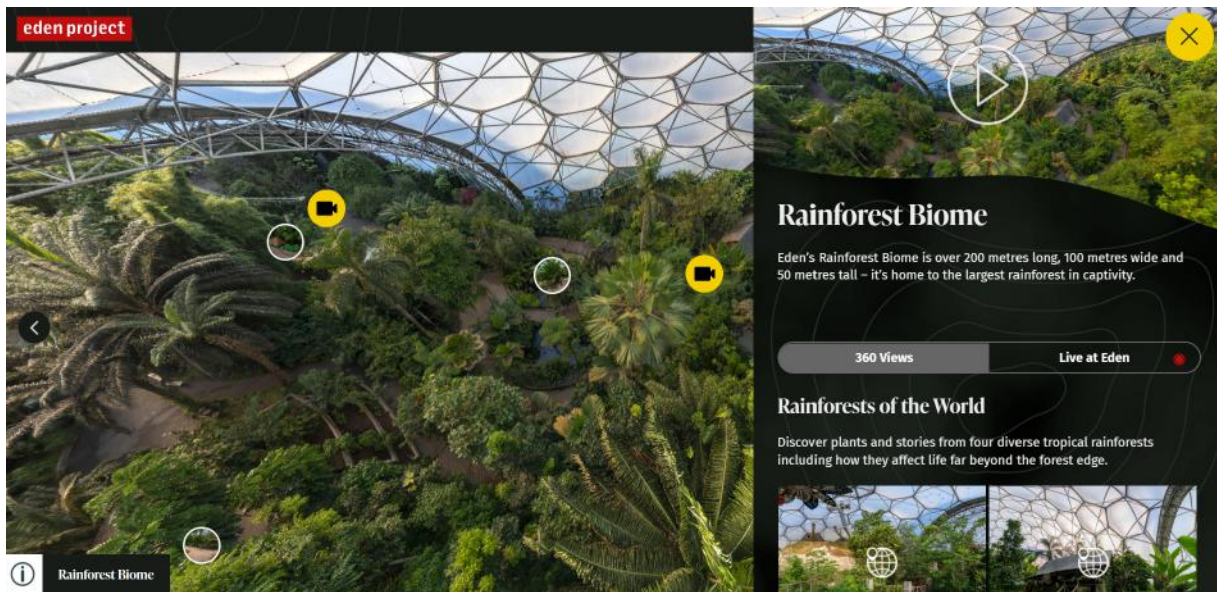


Image 2: Virtual tour Rainforest Biome screenshot

Embedded throughout the tour are various ways our online visitors can access more content about EP. Including:

- Information icons about each main region

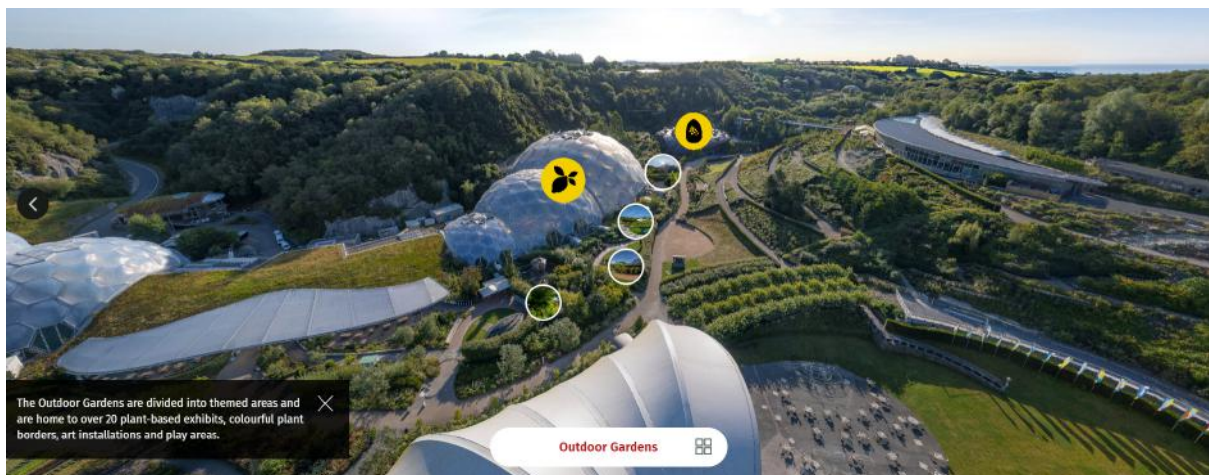


Image 3: Virtual tour screenshot including information icons

- Labels on geographical features



Image 4: Virtual tour screenshot including geographical icons

- Pop-out text boxes with photos about different areas, plants or special features

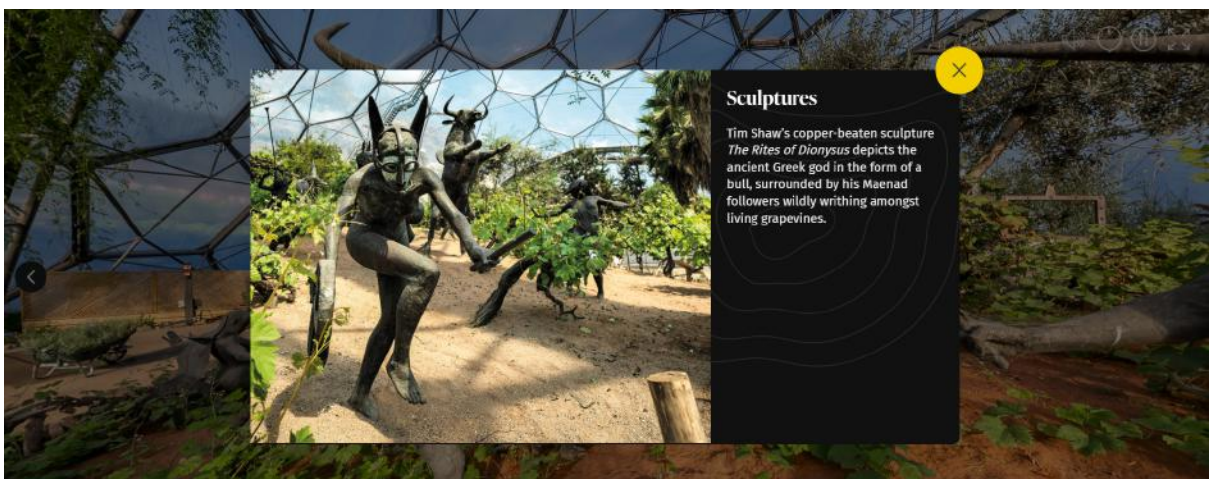


Image 5 & 6: Virtual tour screenshot including pop-out text boxes

Here we have included the content that enables people to understand what EP is all about, view up close a wide range of plants and look around the highlights of the entire site.

The platform was built by 3DeepMedia, with all content directed by the Eden team. 3DeepMedia made two site visits to capture drone footage and supplementary 360° photos, in addition to the META camera feeds.

Virtual Nature experience

Visitors can select to view our virtual nature content from the main menu at the top of the page as well as from the aerial view as they explore. The content has been primarily designed for VR headsets for an immersive experience, but we have included it on the platform as well to understand its effectiveness when viewed through a device (PC, tablet, phone). On the platform version, viewers will need to use their mouse or finger to swipe around the 360° view, or for a more passive, relaxing experience they can choose to sit back and watch and listen to the 360° soundscape.

At this stage we have only produced one nature experience – Dawn in the Outdoor Gardens. This enabled us to test how the experience works before developing additional content as part of the projects’ legacy. We are also limited by the time of year, the weather and lack of flowers outside, as well as low light levels in the Rainforest Biome.

The virtual nature experience was shot using the META roaming camera, with 360° audio recorded at Dawn in the Outdoor Gardens. The film was produced by the Eden team with support from META. We aim to create an experience in the Rainforest Biome at some point throughout the trials, which will be added to the online platform

Visitor Dashboard – Live and Counting

Visitors can access our Live and Counting dashboard, populated by IoT piece of work, by clicking on the ‘Live at Eden’ tab in the main menu. Here we have also included access to our Rainforest Dashboard that is part of the Education use case and all of our Live camera views.

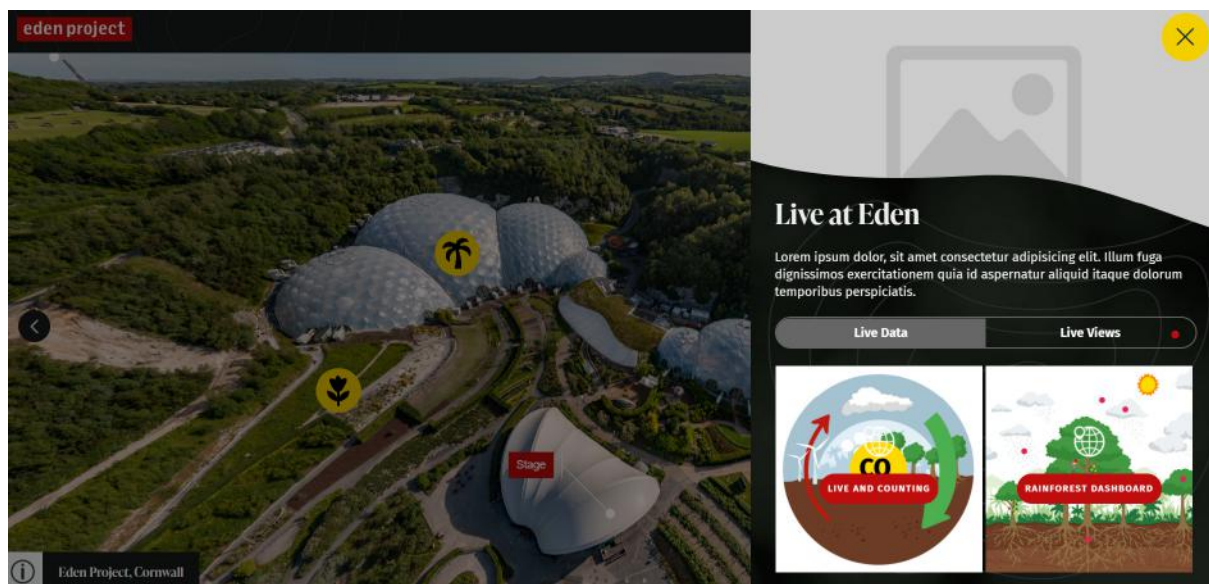


Image 7: Virtual tour screenshot Live at Eden section

Once clicking on ‘Live and Counting’, visitors are introduced to the content – tracking Eden’s progress to climate positive by 2030. We have also included a live global CO₂ widget with contextual information about the climate emergency and a link to Eden’s 11 top tips for halting climate change and biodiversity loss.

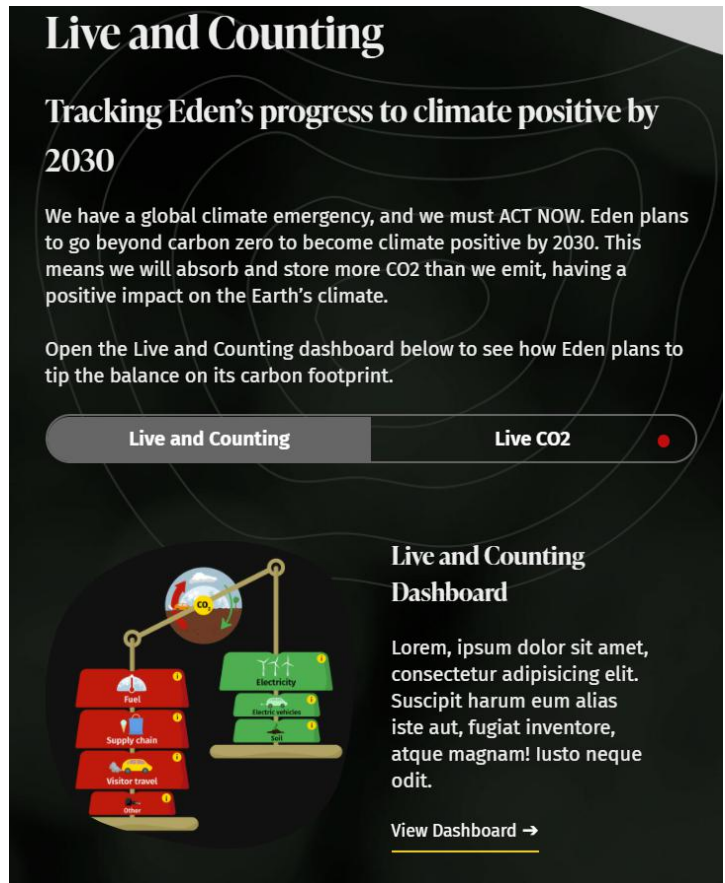


Image 8: Virtual tour screenshot Live and Counting illustration



Image 9: Screenshot of BMS data dashboard

The Live and Counting dashboard is split into two sections. On the left an illustrative graphic display how Eden will tip the balance on its carbon emissions between now and 2030. Viewers can toggle back and forth between today and 2030 to understand Eden's strategy to becoming carbon positive. They can also click on each element to understand more.



Image 10: Virtual tour screenshot Live and Counting illustration

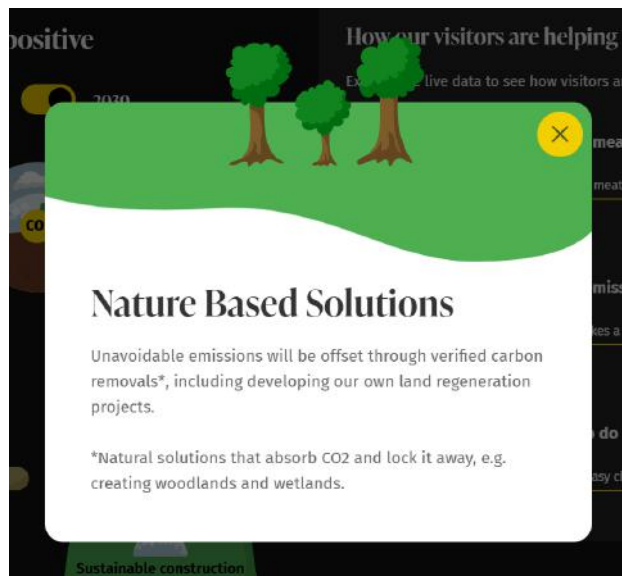


Image 11: Virtual tour screenshot Live and Counting illustration

On the right we feature three live data streams to show how visitors onsite are helping EP reach its targets.

- Meat-free meals purchased by visitors
- Tonnes of CO₂ emissions avoided by visitors recycling
- No. of 'Make the Change' pledge made by visitors (via interactive screen in EP's ice rink)

These live data feeds are linked through to the platform via API's from aq's data lake.

How our visitors are helping

LIVE ●

Explore the live data to see how visitors are making a difference.



... meat free meals purchased today

[Why eating less meat helps →](#)



... of CO₂ emissions avoided by recycling.

[How this makes a difference →](#)



... pledges to do our Make the Change top tips

[Discover what easy changes you can make →](#)

Image 12: Virtual tour screenshot Live and Counting illustration

Live and Counting was created and illustrated by the Eden team, and built on the platform by 3DeepMedia, with technical input from aql for the live feeds.

Invisible Rainforest: Deployment of Invisible World packages online

Working with MLF and 3Deep Media we have developed an online version of our onsite augmented reality (AR) experience in the Rainforest Biome.

Visitors select 'Invisible Rainforest' from the Eden Universe platform, then 'General Public' from the profile page and follow a detailed, comprehensive journey (UX) through the content.

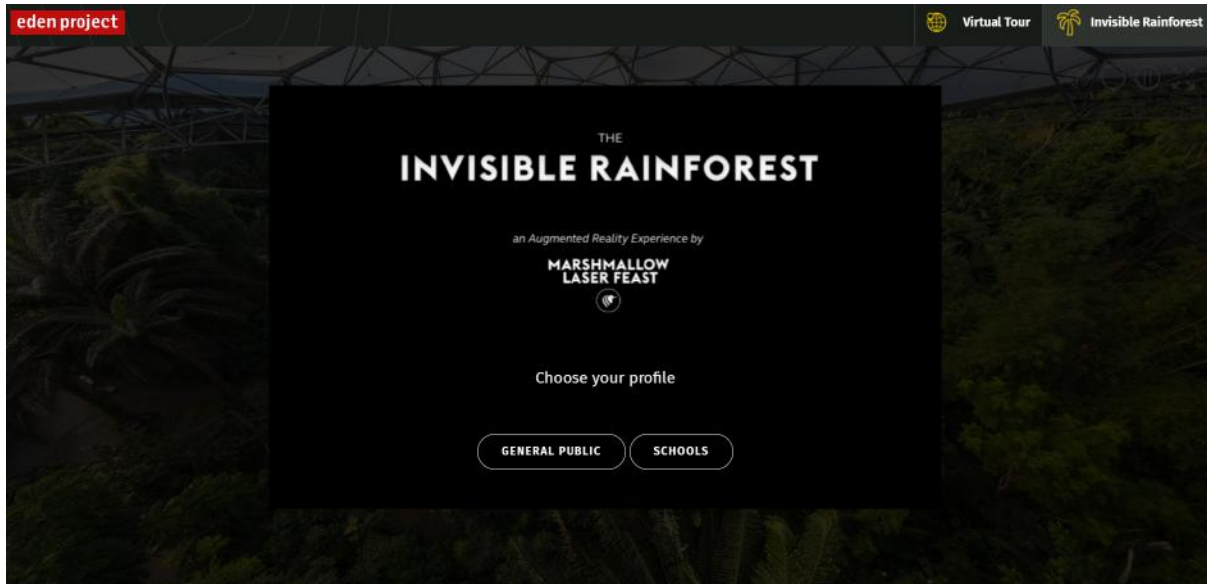


Image 13: Virtual tour screenshot The Invisible Rainforest welcome page

The experience begins with some information about how the experience and AR has been created, followed by an introduction to the experience.

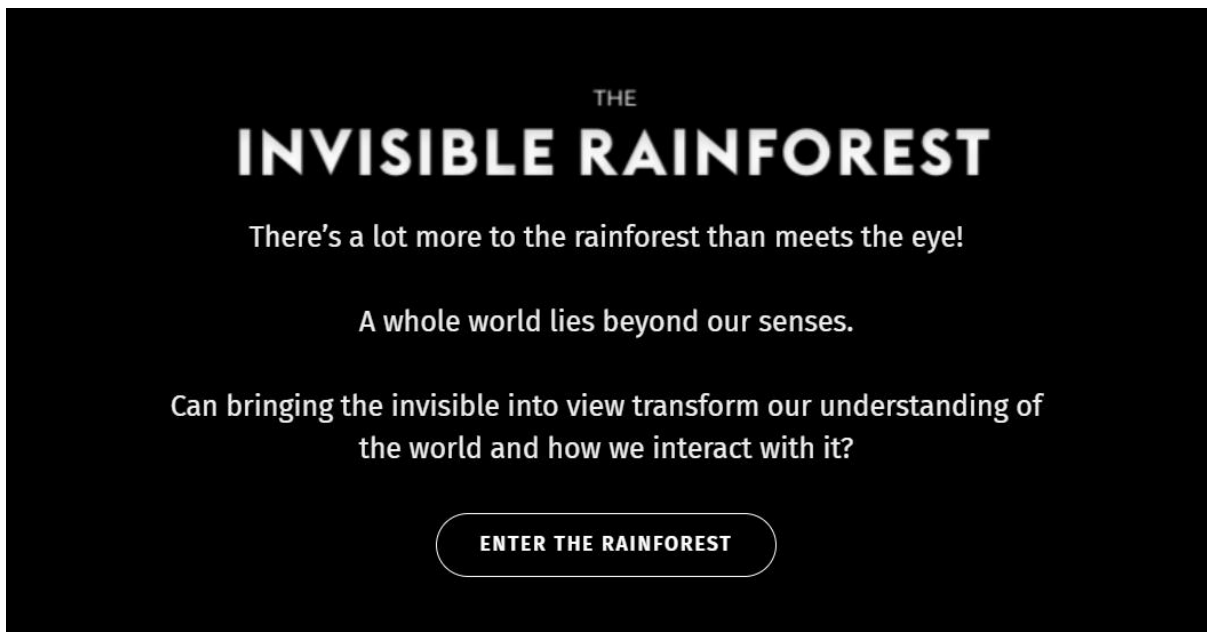


Image 14: Virtual tour screenshot The Invisible Rainforest entry point

Once the viewer enters the Rainforest Biome, they can have a look around a 360° aerial view and discover the three different parts of the journey to explore (detailed below). These can be accessed by clicking the buttons on the screen and following the written steps.



Image 15: Virtual tour screenshot The Invisible Rainforest overview of experiences

- Rainforest Lookout / Rainforest Live - includes the view from the META 360° camera on the Lookout platform in the Biome, when this is not able to be live it will be a pre-recorded version. An AR overlay shows the live environmental conditions in the Biome, including temperature, humidity and light.
- Living Lens: Southeast Asia – begins with a 360° view taken in Southeast Asia area of the Biome, followed by an introduction to the Living Lens experience, an audio description and then a 3-minute video of the Living Lens AR experience with soundscape and voice over.

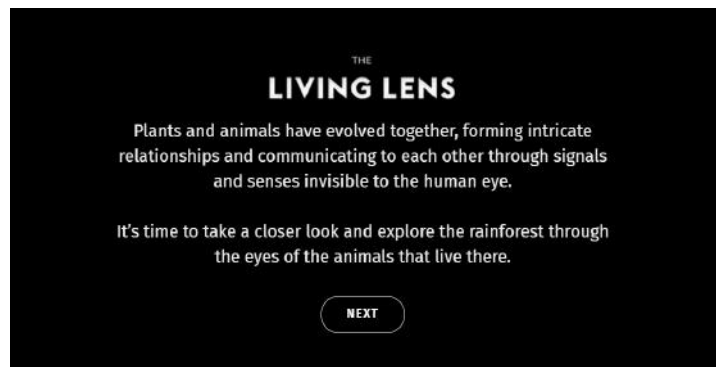


Image 16: Virtual tour screenshot Living Lens introduction

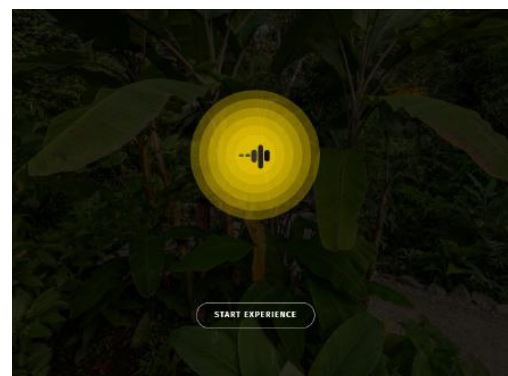


Image 17: Virtual tour screenshot Living Lens narrator

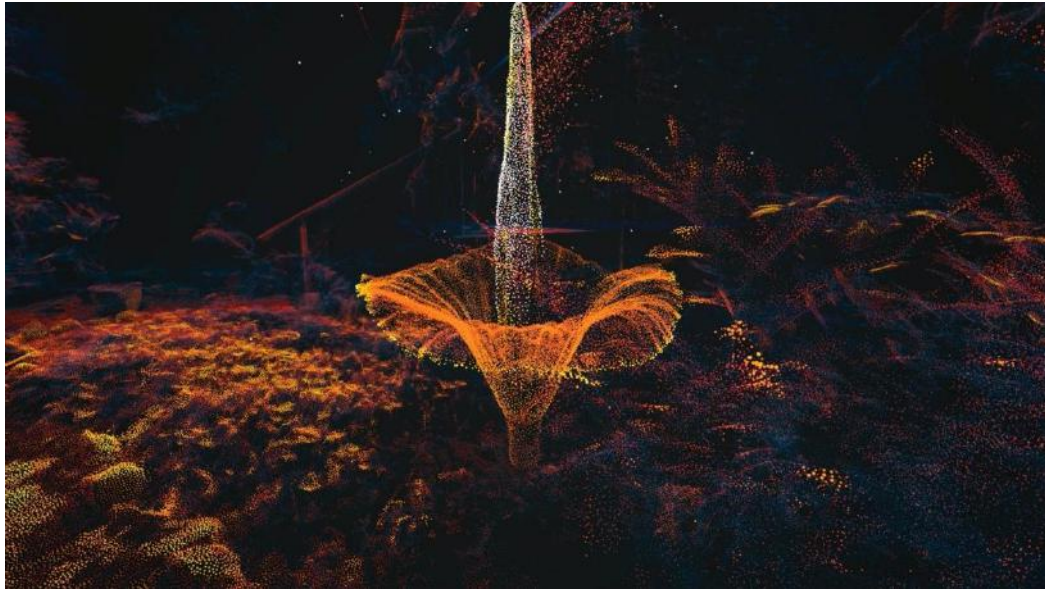


Image 18: Virtual tour screenshot Living Lens – mosquito view

A short reflective summary is shown, before the viewer is redirected back to the aerial view to select the next part of their experience.

- Weather Maker: West Africa – begins with 360° view taken in the West Africa region of the Biome in front of one of the tallest trees in the Biome, where this experience is based. This is followed by an introduction and an audio description before the viewer joins the live stream of the META vertical camera with the Weather Maker AR overlay. The full experience is a cycle up and down the tree and lasts 6-minutes. When this can't be live, viewers will be directed to a pre-recorded version.

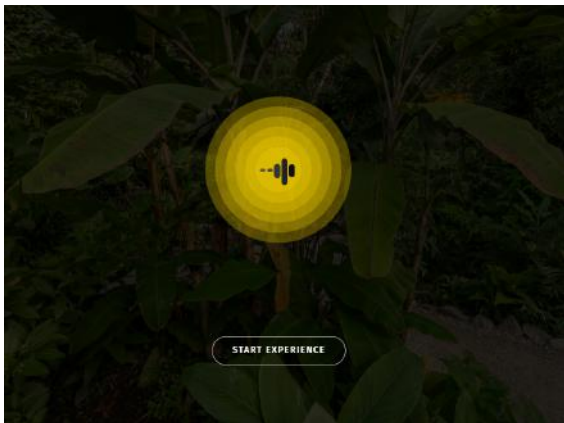
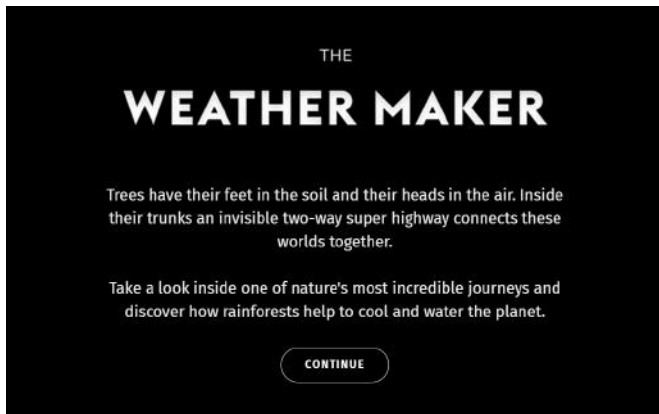


Image 19: Virtual tour screenshot Weather Maker introduction

Image 20: Virtual tour screenshot Weather Maker narrator



Image 21: Virtual tour screenshot Weather Maker carbon canopy

A short reflective summary is shown, before the viewer is directed to take the survey for evaluation purposes.

The narrative is based on viewing the invisible worlds inside a rainforest, with the hope to increase understanding about the interconnectedness of life and the environment and to remind people that we are all part of nature, not apart from it.

The online experience was built by 3DeepMedia, created and directed by Eden team and MLF. MLF produced all AR video and audio assets. For online both the Living Lens and the Weather Maker are rendered video versions of the content, and therefore have a higher resolution than the onsite

versions (detailed below). This was important for the online visitor to gain a full understanding of the content without being in the physical space with a tour guide.

Visitor Experience – on site

Invisible Rainforest: Deployment of Invisible World packages onsite

Visitor trial groups are met by their ‘Invisible Rainforest’ tour guide outside of the Rainforest Biome, where they are introduced to the kit they will be using (iPad’s with tethers for safety and headsets). Here they put on and test their devices. Groups are limited to three people max at present but we are hoping to increase these numbers as the pilots develop.

Visitors are then led inside and around the Rainforest Biome and introduced to the two AR experiences (Living Lens and Weather Maker) at their set locations. The tour guide delivers a set narrative at each location that delves into the Invisible Rainforest and asks people to question what insights we can gain from going beyond our own senses and visualising the invisible through the power of AR.

The journey and narrative is split across the Biome in nine steps as shown below.

Map of Rainforest Biome and Onsite Journey

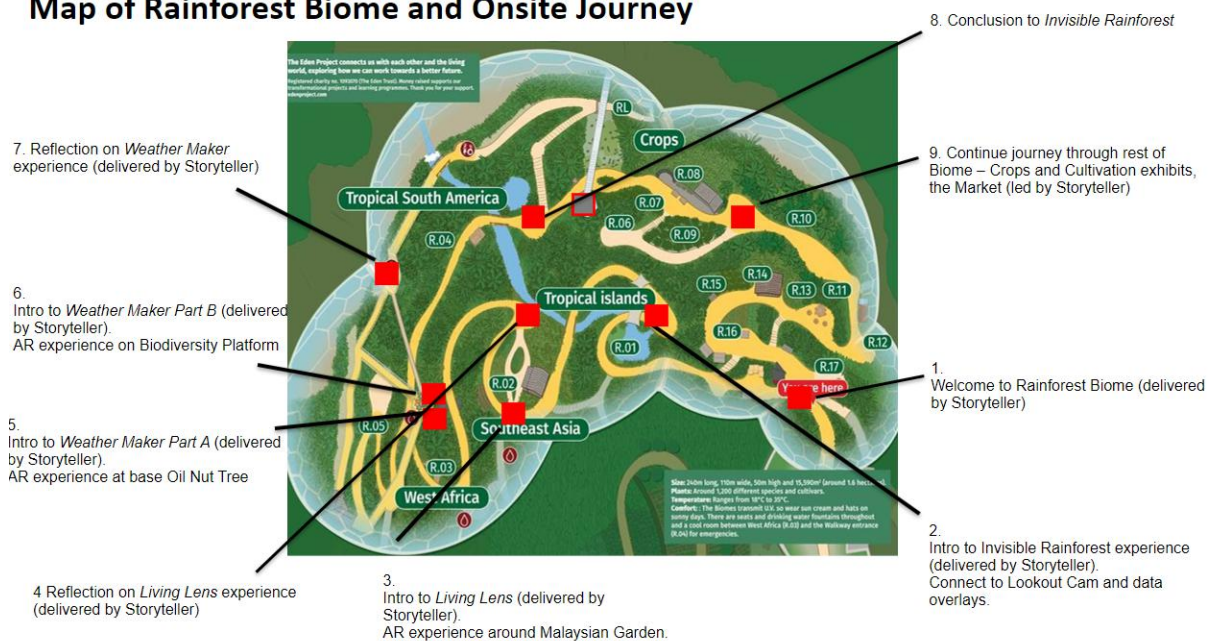


Image 22: Map of Rainforest Biome onsite experience journey

Visitors engage with the AR content at four main locations:

LOCATION ONE: Visitors initiate devices and view the 360° view of the Rainforest Biome from the Lookout Meta 3 camera with the data overlay, displaying information on temperature, humidity and light in the Biome. When this view is active through the live stream platform they will also be able to spot themselves in the picture – a tiny human about to enter a vast rainforest. Here the tour guide introduces the group to the Invisible Rainforest and the importance of the invisible systems and cycles that sustain life on Earth.



Image 23: Sample group taking part in onsite experience

LOCATION TWO: At Southeast Asia within the Rainforest Biome – the group begins at the edge of EP’s Malaysian Garden. After a verbal introduction by the tour guide, they initiate their devices and are led through the garden, viewing and listening to the content as they go. First, they view the garden as a mosquito, then as a bee and finally as a bat. As they transition from one view to the next, they experience what it might be like to sense certain signals in the environment. The mosquito senses infrared radiation and CO₂, the bee detects UV light and static electricity, and the bat navigates using echolocation. The narrative explores the special relationship each species has with a plant growing in the garden.



Image 24: Sample group taking part in onsite experience



Image 25: AR onsite experience – Mosquito view of titan arum



Image 26: AR onsite experience – Bee view of plants in garden



Image 27: AR onsite experience – Bat view of jade vine flowers

After a short period of reflection, the group is led from the Living Lens experience to the Weather Maker experience by the tour guide at, who delivers a linking narrative, explaining that they have seen the intimate connections that exist between different species, but now they will view the invisible cycles of carbon and water, that connect all life to the environment, including humans.

LOCATION THREE: At West Africa – Part one: Soil.

The group begins at the edge of a pathway through the forest to the Weather Maker tree. After a verbal introduction by the tour guide, they initiate their devices and are led along the path, viewing and listening to the content as they go. They first view the absorption of CO₂ gas from the air into the leaves of plants all around, watching the journey of the CO₂ into sugar as its taken up and used by the plants. Next, they follow the passing of the sugar into the mycelium (fungal) network that appears under the soil. Raindrops start falling on the pathway and are absorbed into the network, before being taken up by the plants. The viewers' attention is drawn to the base of the large tree, here they follow the journey of the water up the tree trunk.



Image 28: AR onsite experience – Introduction to Weather Maker by the tour guide



Image 29: AR onsite experience – View of fungal network under the soil

LOCATION FOUR: At Biodiversity Platform – Part two: Air

After a short reflection, the group follows the guide up to a higher vantage point of the same tree. The experience continues from the Biodiversity Platform. Here they receive a short introduction by the guide, calibrate devices and then continue the journey where they left off. They view the journey of water up the tree and out into the atmosphere. In the air water particles form rivers that flow above the tree. The experience ends on hearing and visualising the falling of rain all around them.



Image 30: AR onsite experience – Weather Maker from the Biodiversity Platform

At the end of the experience, the guide delivers a conclusion to the Weather Maker, summarising the vital importance of the rainforest in regulating the world's climate via the cycles of carbon and water, that they have just witnessed.

The tour guide delivers a conclusion to the Invisible Rainforest experience further around the Biome (after travelling past the waterfall), posing some reflective questions about what they have just experienced. Finally, visitors follow the guide towards the exit of the Biome to be met by the evaluation team.

The onsite narrative was created and directed by the Eden team, including the production of voice overs for the AR experiences. The AR was created by MLF, with some creative direction from Eden team. The onsite AR experience differs slightly from the online version. In the Living Lens, the iPads are recognising and interpreting the environment in real-time, meaning its vital for visitors to move slowly through the space, everyone's experience will be slightly unique. In Weather Maker, the AR is mapped to the exact environment, which is revealed as visitors navigate the space.

USE CASE TWO: EDUCATION

Thanks to the technologies installed as part of the Eden Universe the Educational team have developed three offers for the education exemplar utilising the content created as part of the visitor experience. These offers allow us to test the technology with students from KS1 to KS4. In addition, it has afforded us the flexibility and scope to trial different modes of delivery and access points into the materials.

Offer 1

Age: KS1 (years 1 and 2)

Duration: 60 minutes

Format: Led by class teacher on demand.

Technology utilised: Living Lens augmented reality (AR) video, 360° META lookout camera, 360° view of Southeast Asia.

Supporting material: Sent to teacher in advance and to include a written lesson plan, resource list (if required), PowerPoint, vocabulary list, Information about how to use the web platform.

Title: Invisible Rainforest: Super Senses

Key Enquiry question: What would my Super Sense be?

Learning Outcomes:

- Locate some of the world's Tropical Rainforests describing what conditions are like there and why they are ideal for plant growth.
- Identify the 'super sense' of three different rainforest animals and describe in simple terms how they use their 'super sense' to find their food.
- Summarise the animal/plant relationships they have learnt about in terms of how they depend on each other (interdependence); in two of the examples the animal pollinates the flower and in return receives nectar.

Workshop Summary

The session begins with a quick activity outside which is designed to get the students to tune into their five senses.

On return to the classroom, the teacher has been granted the ability to access the online content by selecting 'Invisible Rainforest' from the Eden Universe platform, then 'Schools > KS1 Living Lens' from the profile page.

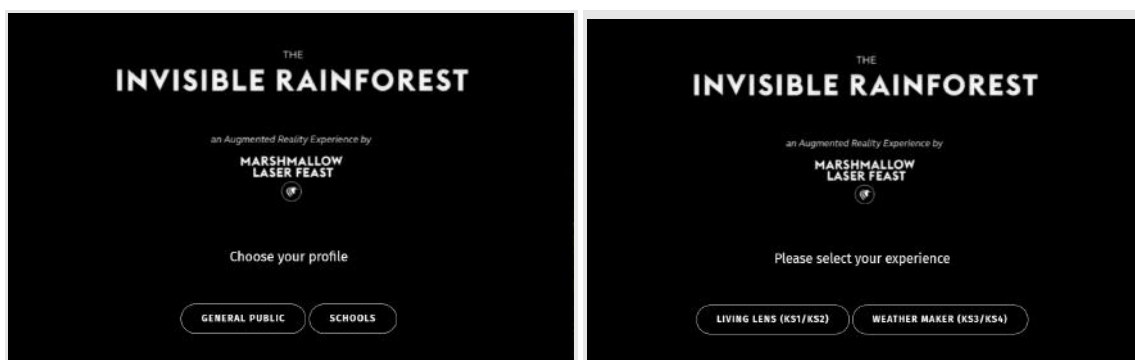


Image 31 & 32: Educational experience platform welcome

The experience begins with some information about how the experience and AR has been created, followed by an introduction to the experience.

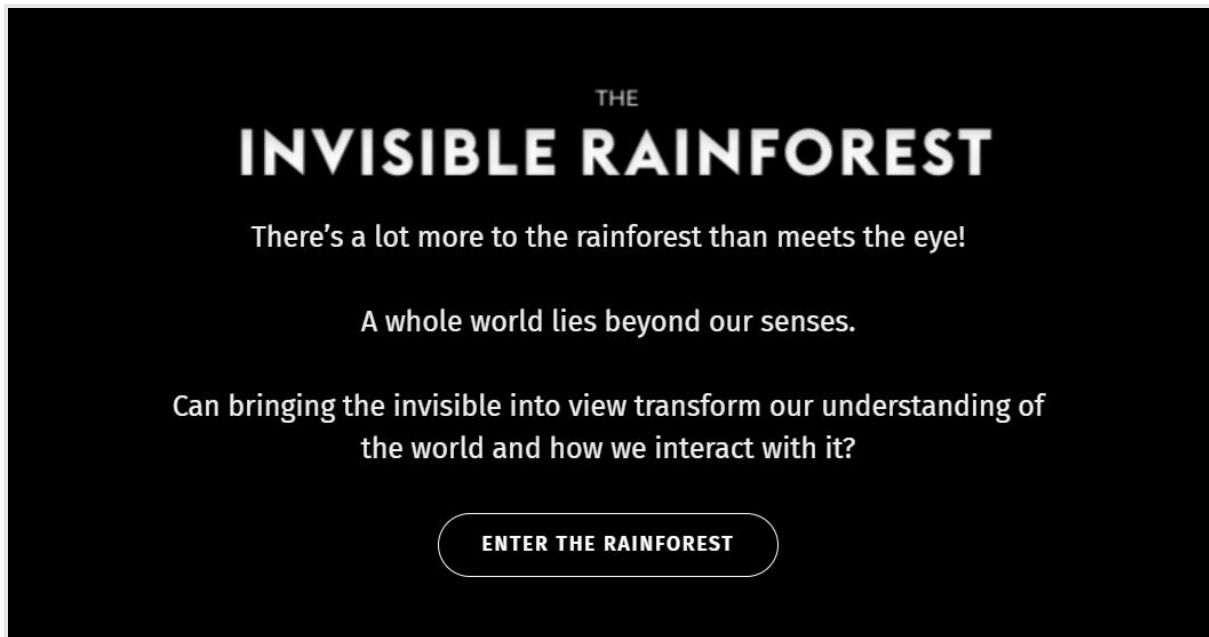


Image 33: Educational experience platform welcome

Once the teacher enters the Rainforest Biome, they can utilise the 360° aerial view and discover where the Living Lens experience is based in Southeast Asia in the Rainforest Biome. The experience is then accessed by clicking the button on the screen and following the written steps.



Image 34: Educational experience virtual tour platform overview

The teacher can choose to first view the Rainforest Lookout/Rainforest Live META 360° camera on the Lookout platform in the Biome. An AR overlay shows the live environmental conditions in the Biome, including temperature, humidity and light. When this can't be live, a pre-recorded version is shown.

The students are asked to consider what it would be like in a Tropical Rainforest. What might they see, hear, taste, touch, smell and how that differs from where they currently are? The data dashboard will help with this comparison.

When the teacher selects Living Lens – Southeast Asia from the aerial view, they will be transported to a 360° view of this region in the Rainforest Biome and given the chance to have a lookout the view.

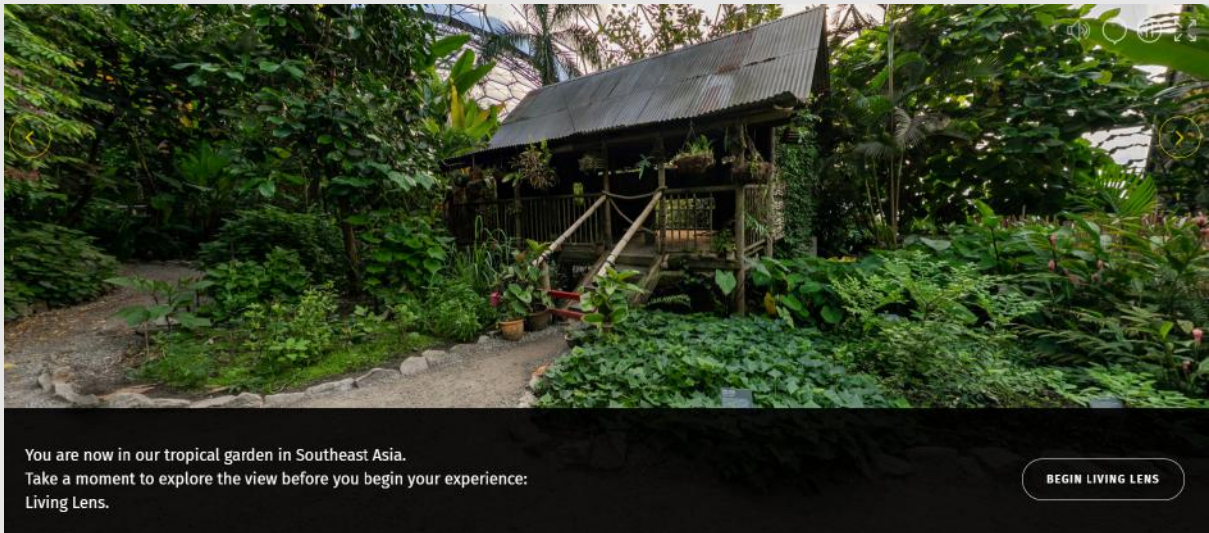


Image 35: Educational experience living lens welcome

When ready they begin the Living Lens experience which starts with a short introduction, before the children are introduced to some animals from the Tropical Rainforest that have very unusual senses compared to ours.

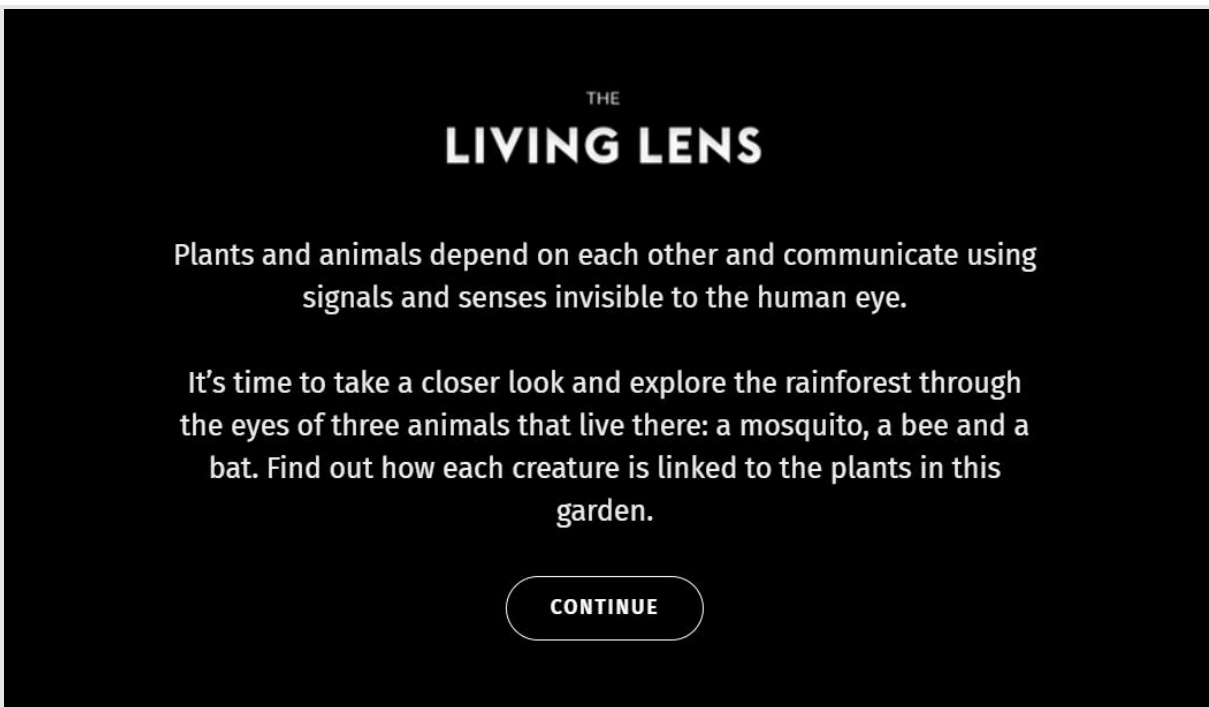



Image 36: Educational experience living lens welcome

By clicking on the three labels on the 360° view, they can explore three different plants (titan arum, starfruit tree, jade vine), and the animal that is attracted to them via their super-sense (mosquito, bee and bat).




Image 37: Educational experience information icons



Titan Arum

Titan arums form the largest flowers on Earth. When they bloom, their temperatures rise to 37 degrees and they release smells that are carried on the air to pollinators.

Mosquito




By sensing heat and carbon dioxide, female mosquitoes look for warm-blooded mammals to feed on.

How does the titan arum trick the mosquito into paying it a visit?

[FIND OUT MORE](#)


Image 38: Educational experience information box



Star fruit tree

Star fruit trees produce sweet and sour yellow fruits and clusters of tiny lilac flowers.

Stingless bee



Bees find flowers using UV vision. This small black stingless bee likes the nectar of the star fruit flower and is an important pollinator of the star fruit tree.

How does the star fruit tree attract the bee?

[FIND OUT MORE](#)

Image 39: Educational experience information box

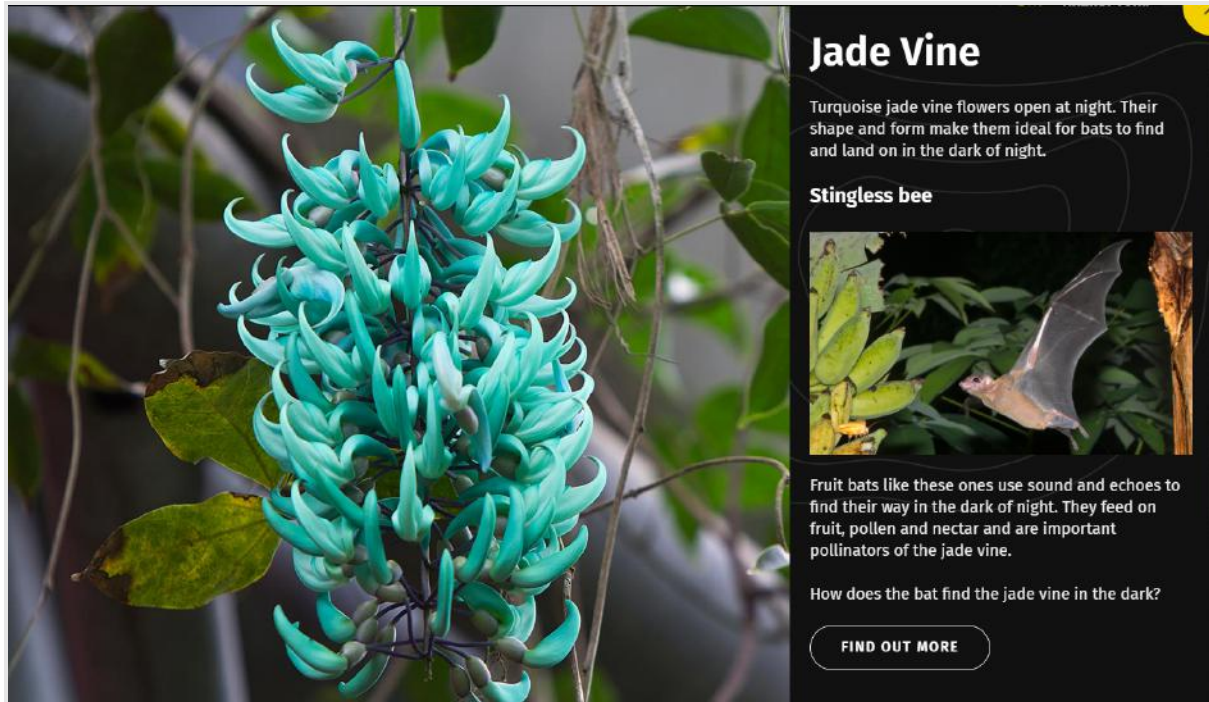


Image 40: Educational experience information box

From each of these pop-up information boxes the class can select a video of the Living Lens AR journey for each species view of the rainforest, these videos are the same as used in the virtual tour and AR tour. Each video is about 1-minute long and has a soundscape and bespoke voiceover designed for this age group.

After the class has viewed each video, they complete a short role play in the character of each animal to get them moving around the room. The students will complete a card sorting activity to consolidate the learning from the Living Lens.

Finally, they embark on a trip with the 360° cable Camera, taking a flight through the forest before considering what they would like their 'Super Sense' to be if they had to survive in the Tropical Rainforest.

One of the suggested follow up activities is to create an artwork which shows what your Tropical Rainforest Super Sense would be and how it would help you to survive there?

Students could share their work with us via twitter @edenschoolsteam.

Offer 2

Age: Key Stage 2

Duration: 60 minutes

Format: Led by Eden education officer from the core building at Eden Project, Cornwall and streamed into the school classroom via Zoom. Teacher is with the class and helps to facilitate the session from their end.

Technology utilised: Living Lens augmented reality (AR) video, 360° META lookout camera, 360° view of Southeast Asia. 360° marketplace camera.

Supporting material: Sent to teacher in advance and to include resources to print.

Title: Invisible Rainforest: Signals and Senses

Key Enquiry question: What can humans learn from the way that nature works?

Learning Outcomes:

- Locate some of the world's Tropical Rainforests, describing what conditions are like there and why they are ideal for plant growth.
- Define what is meant by the term biodiversity and classify some examples of Rainforest biodiversity.
- Give examples of unusual adaptations that help animals to survive in the Rainforest
- Describe examples of interdependence between living things in the Rainforest.
- Explain why humans are also dependent on rainforests and ecosystems.

Workshop Summary

This session shares some similar activities to the KS1 session. However, one of the key differences lies in the fact that the Eden education team will deliver this session live to the group from Eden Projects Core building rather than the teacher facilitating the session for themselves on an on-demand basis. The Eden team member will access the online content from the Eden Universe platform, this time selecting the Living Lens KS2 experience from the profile page and sharing their screen with the class.

The children begin the session by considering where in the world we find Tropical Rainforests and what conditions are like there. The education officer delivering the session shows the students around using the 360° lookout camera in order to facilitate this. We discuss why plants grow so well in the tropics and introduce the idea of biodiversity through playing a classification activity involving animals from the rainforest.

Three of the animals from the classification activity are the same as the animals from the Living Lens experience (the bat, bee and mosquito). At this point we continue on the Living Lens journey (as described in the KS1 experience detailed above). The key difference in the experience being that we have used the same voice over as the public experience for this age group. We complete an activity to consolidate their learning.

This activity leads into a discussion about what the plants receive from the animals – pollination services and into the wider idea of symbiosis and interdependence.

We conclude by considering how humans are also dependent on the Tropical Rainforest for survival. The final step of the experience, involves sharing the Virtual Tour from the Eden Universe platform (detailed in report D6.5a). The class leader can show the children around the different views of the Rainforest Biome, by clicking on the live META 360° camera streams. We use the market camera to help give examples of the kinds of things the rainforest gives us. We return to the lookout camera and as a parting thought we ask the students to suggest what they have learnt from the way that nature works - We are not separate from the natural world around us - we are a part of it.

Offer 3

Age: Key Stage 3/4

Duration: 60 minutes

Format: Led by Eden Project education officer live from the Rainforest Biome and broadcast into the school classrooms via Zoom. The teachers are with the classes and help to facilitate the session from their end. This is a broadcast (1 to many)

Technology utilised: Weather Maker AR experience, Rainforest dashboard, 360° META camera live streams.

Additional technology required: Likely broadcast via ZOOM from the Rainforest Biome using a smart phone, DJI gimble, tripod mount, wireless head set. Moderator located in alternative location to act as host and control AR, presentation slides for the presenter.

Eden team can see into the classroom, but because it is a broadcast participants will be on mute (controlled by moderator).

Title: 'Invisible Rainforest: Climate Control'

Key Enquiry question: 'How are humans connected to ecosystems, global cycles and challenges?'

Learning Outcomes:

- Describe the science behind the greenhouse effect and the causes of climate change.
- Explain the key biological plant processes of photosynthesis and transpiration and consider them in the context of the global carbon and water cycles.
- Analyse data from a rainforest and suggest reasons for changes in parameters such as Carbon dioxide levels and Relative humidity over a 24-hour period.
- Consider how climate change might impact on the global carbon and water cycles.
- Discuss the significance of the role played by trees in climate change mitigation and the wider importance of forests.

Workshop Summary

This session is delivered live from the Rainforest Biome. We begin by joining the presenter in the rainforest who introduces the group to the scale of the rainforest and shows the students the roof of the biome. The presenter is able to show the students around using the smartphone/gimble set-up. The host will begin the Weather Maker experience from the platform, clicking through the steps in the journey, before reaching the start of the AR experience.

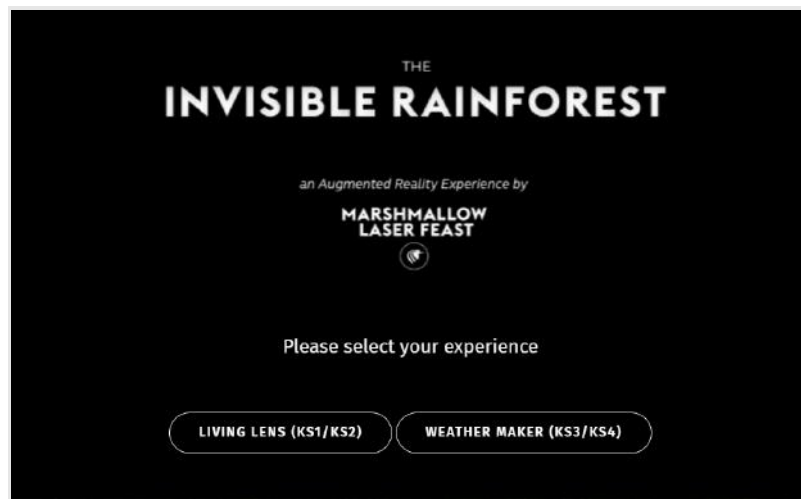


Image 41: Educational experience welcome

They first select the 360° lookout camera/Rainforest Live from the aerial view and use it to find the presenter on the live YouTube feed coming from the camera above and also to show the students around.



Image 42: Educational experience icon overview

The presenter asks the students how they think we keep it warm enough for the plants in there? The classes are encouraged to communicate their ideas through the chat function and this information is then shared with the presenter by the moderator based in the Core building at Eden. The presenter then uses the Biome as an analogy to explain how the greenhouse effect works. This leads into a brief review of the causes of climate change. The presenter has the option of placing the Smartphone on a stationary tripod.

After a brief discussion about the importance of trees the students are shown the Weather Maker experience in West Africa in order to understand what is happening inside of trees in terms of photosynthesis and transpiration and how this links to the global carbon and water cycles. The host will either start the experience from the online platform or by playing the video directly (depending on which has better resolution). We have chosen to play the students a pre-recorded version of the Weather Maker AR, rather than the live version from the vertical camera as that we can choose the start of the experience and pause the video if needed.

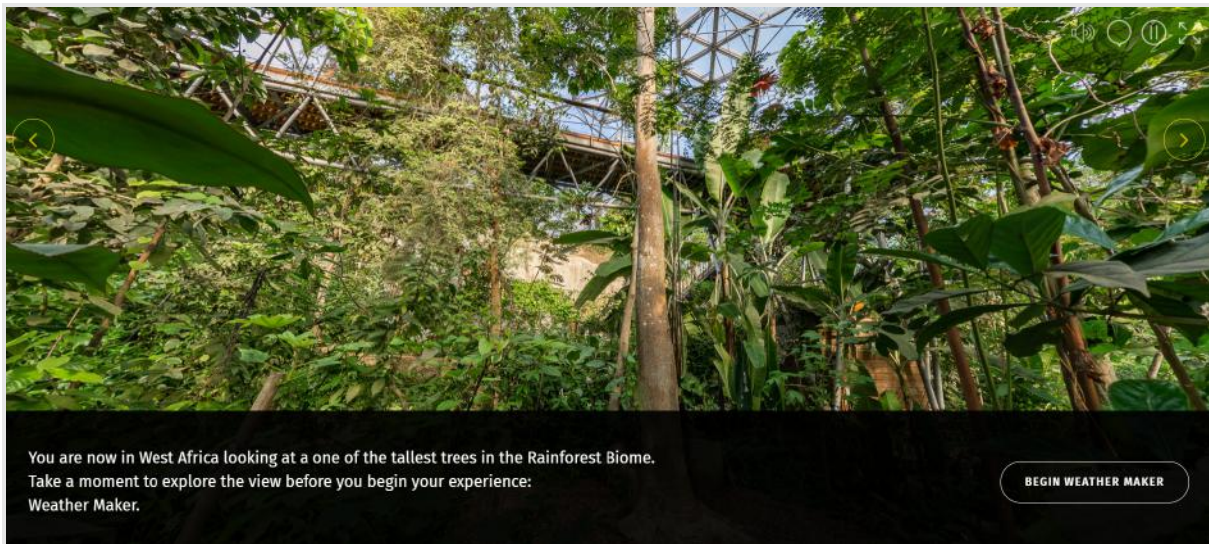


Image 43: Educational experience Weather Maker opening



Image 43: Educational experience Weather Maker AR experience

At the end the students complete an activity to consolidate this learning.

The lesson continues by accessing the Rainforest Dashboard from the next step on the online platform. It is used to help the students visualise how various parameters in the rainforest change over the course of 24-hours linked to what they have just learnt about photosynthesis and respiration. We also use the dashboard to consider how the various plots on the graph might look different as climate change accelerates.

The Rainforest Dashboard is split into three sections:

- On the left we have created an illustration animation that explains how rainforests help to regulate the climate. Here pop-up text boxes reveal more information.
- On the right we have created an illustration of how conditions change in the real rainforest over time. The different lines on the graph can be switched off and on.

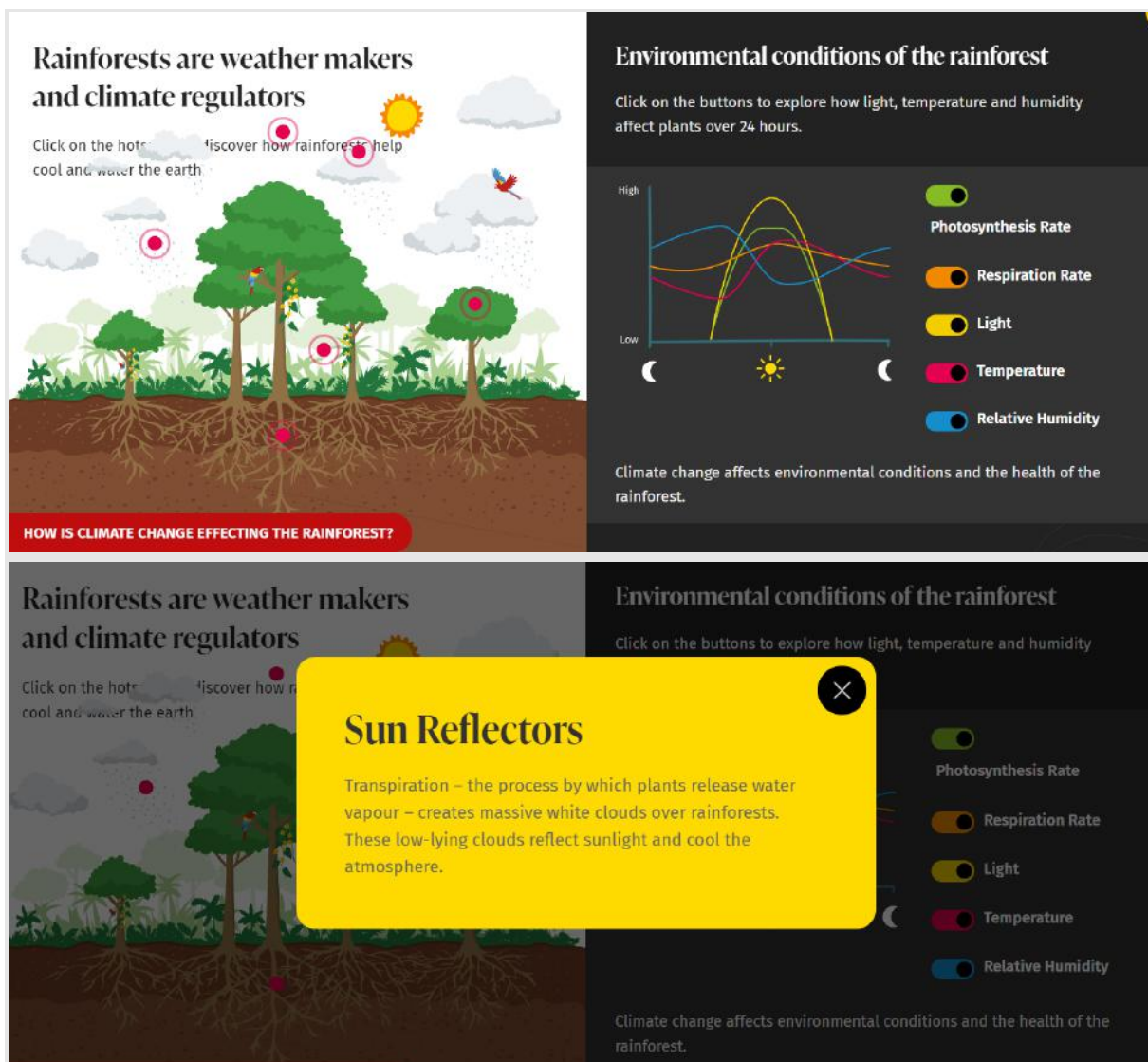


Image 44: Educational experience Data Dashboard content

- At the bottom we show the live environmental conditions around Eden Project, from the Rainforest and Mediterranean Biomes and from the Outdoor Gardens. This provides a good comparison and talking point for the students.

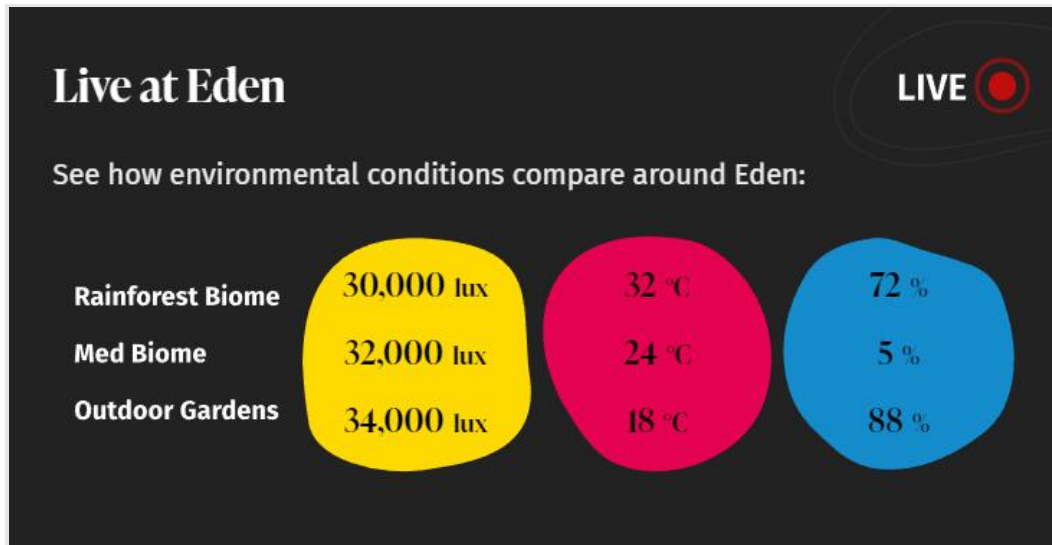


Image 45: Educational experience Data Dashboard content

Lastly, there is a section that explores how climate change is affecting the rainforests. the host returns to the 360° lookout camera to highlight some of the largest trees in the biome and the students play a game to guess how much carbon dioxide they think those trees have absorbed in their life time. We compare this to the average carbon footprint of a UK citizen and the students debate whether they think we could grow enough trees to offset our global carbon emissions and 'solve' climate change. We reach the conclusion that this isn't going to be possible.

The presenter summarises that trees are an important part of the puzzle in terms of climate change mitigation (through carbon dioxide sequestration) but they are not the whole answer. Forests on their own can't 'save us' but reminding the students of all the other reasons why trees / forests are important.

Finally, we return to the 360° lookout camera, the presenter asks the students to share what they think to the question; What do you see as the key solutions to climate change? The presenter collects feedback via the moderator and discusses the ideas raised.

As a parting thought the presenter comes back to a view the rainforest and comments on its beauty and how everything in the rainforest has a role to play and is connected. There are countless examples from the rainforests of how the living things help each other survive (ref to the mycorrhizae in the Weather Maker experience) and if we can learn anything from the rainforest that would help us with the current challenges, we face it would be about how we can all work together. Eden itself is also a symbol of what can be achieve when we do that.

USE CASE THREE: HEALTH & WELLBEING

Our third exemplar was developed utilising the content developed on the Eden Universe Virtual Tour, the objective was to create experiences that could be utilised by care home residents to assess whether it could improve their quality of life or help them feel more connected to the living world and other people.

This content was then delivered in three different formats at four different care homes:

- Care home 1 – St Breock, Wadebridge (Individual iPad experience) – Via the Eden Universe platform loaded onto iPads with individual headsets.
- Care home 2 – Woodlands, St Austell (Group projector experience) – Via the Eden Universe platform projected onto large screen in communal room with speakers.
- Care home 3 – Headland, St Ives (Immersive VR experience) – Via VR headsets pre-loaded with content.
- Care home 4 – Rowan Garth, Liverpool (All three experiences)

Care home residents were able to explore the content through their different devices throughout the trial period following an activity plan put together by the Eden team, Plymouth university and the care homes activity leaders. The activity plan will suggest which parts of the content they may like to trial within different sessions, so that they get to work through all the content in bitesize chunks. For example, one session may be taken up exploring the Rainforest Biome from the Virtual Tour, another session may be taken up exploring the Weather Maker experience in Invisible Rainforest.

Both Care homes 1 and 2 will have access to all the content on the online platform, including:

- The Virtual Tour
- Virtual Nature
- Live at Eden
- Invisible Rainforest – here they select ‘General Public’ profile, rather than Schools.

Online visitor experience.

Residents in Care home 1 will be guided how to use the iPads and explore the content with the activity leader on hand to help.

Residents in Care home 2 will view the content as a group, all taking part in directing the activity leader which part of the experiences they’d like to view and being able to discuss these as a group. The activity leader will navigate the content using an iPad that is connected to the projector screen. Care home 3 will be able to explore:

- Virtual Nature through immersive VR headsets with spatial sound (detailed in report D6.2a)
- A bespoke VR tour of the Eden Project (detailed below).

Virtual Reality Tour

The VR tour was developed to be able to be accessed through these Oculus Quest 2 VR headsets:

Using the 360° META video cameras we captured video from various locations at Eden Project to deliver an effective introduction to Eden and a concise tour around the main points of interest. The tour has been spilt apart into the different regions of the site, so that participants may watch each film in separate sessions, including the Outdoor Gardens, Rainforest Biome and Mediterranean Biome. Each of these three films is approximately 4-5 minutes in duration.

A presenter/tour guide (Nathan) appears throughout the tour to make the experience more personal and to give the feeling of a VIP tour, whilst there are no other visitors there. We therefore went to lengths to record all content out of opening hours. The tour guide starts with a brief explainer of how to get the most from the headsets, suggesting that residents look left, right, up and down.

A voice over continues throughout the tour when the guide isn't in shot to give a seamless experience of being taken on a journey, with the main features in the shot pointed out to the viewer to have a look at. Ambient sound was recorded via a 360° mic which will give the impression that the viewer is stood/or sat in the space.



Image 46: Health & Wellbeing VR headset experience content



Image 47: Health & Wellbeing VR headset experience content

Eden team worked with 3DeepMedia to record the video and audio content. 3Deep were trained by META in use of the roaming cameras. Eden team wrote and directed all content.

USE CASE FOUR: ART & CULTURE

In deployment of the final use case The Eden Universe live streamed a bespoke curated Art & Culture experience entitled “Rainforest Reconnect”.

The performance was curated with multiple teams to deliver a live streamed event that utilised as many elements of the Eden Universe equipment & network as possible.

The focal content of the event was the performance of five tracks produced by Alice Boyd – the five tracks were created during a residency at Eden where Alice collected data from the plants in the rainforest biome. With help from her mentors and instructions off the internet, Alice built a device that detects changes in the electrical current across a plant’s leaves. This variation is then translated into musical notes that can be played by synthesisers and musical software.

Alice used the data collected to create electronic scores that were enhanced with lyrics, instrumental parts and archive field recordings, which together tell a story about our relationship with the natural world.

The Eden team then utilised the music as a starting point to curate visual stimuli that would be most effective through the use of the static and roaming 360° cameras. After numerous mind-mapping meetings, the theme of wellness was finalised for the event and Breathe Yoga were consulted to work with us to create wellness activities that could be utilised alongside the audio tracks.

With this content confirmed we were then able to create a detailed storyboard/‘showflow’ as to which tracks worked best with which cameras/locations in the biome for a customer experience and practicality of delivery.

This included uses of a roaming camera where the singers were situated in a circular position around the lenses to encourage viewers to move the camera view, and use of the vertical camera by placing yoga movements up high on the biodiversity deck of the biome, enabling us to utilise a shot that started at the top of the biome and then travelling down for a closer look.

Once we had the list of shots and understanding of the content we then contracted a third-party contractor, TruCru to act as production company for the event. Based on our requirements they provided venue/event lighting, audio support and technical consultation to ensure we delivered the most aesthetically appealing event possible.

The event was to be streamed on YouTube, via the Eden Project website through creating a specific page for the event to act as a lobby, viewing platform and conduit for the survey.

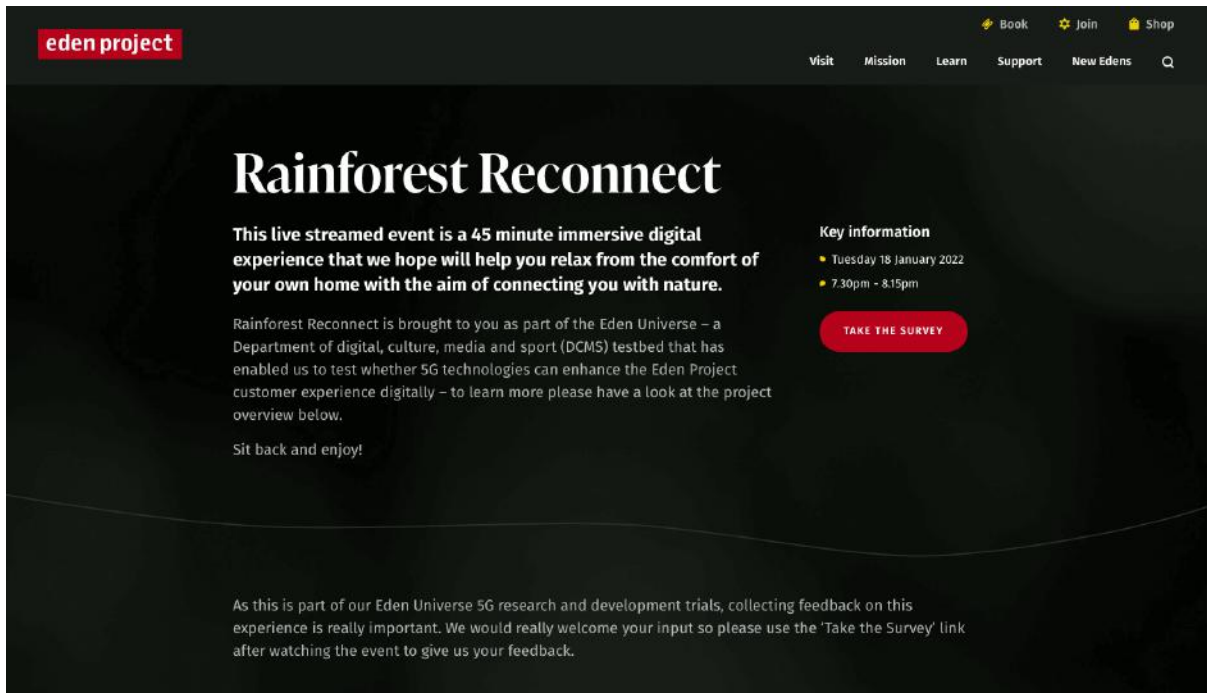


Image 48: Art & Culture event user platform

This page was put in place 7 days prior to the event – to enable us to run rehearsals and testing. We also created a separate page titled “rehearsal” so that guests didn’t see ‘behind the curtain’ prior to the event.

The stream key was created by the Eden team and then META sent the required feed to the correct location.

Meta Camera were responsible for the ingestion, switching and live streaming of the 360° cameras, live and pre-recorded audio and final output.

Each camera transmits two fisheye images over wired or wireless network to the workstation that was temporarily set up within the Eden Project Rainforest biome. This was done for the convenience of a live event environment but could equally have been done remotely with appropriate video and audio communications from the various performance sites.

The workstation stitches the two fisheye images in real time to an equirectangular image using Meta Cameras custom stitching plugin for OBS. The workstation outputs the video as NDI signal over the install fibre network. A separate workstation was used to switch between the different NDI sources in NDI and create a real time edit which is then pushed to YouTube via an RTMP stream in 4K.

There was an amount of work necessary to adjust the audio stream to sync into the video as the system in its entirety created various lag points. However, the workstation and custom software allowed for this, and the sync was achieved seamlessly.



Image 49: Art & Culture streaming set up



Image 50: Art & Culture lighting set up



Image 51: Art & Culture head of streaming



Image 52: Art & Culture choir performance area – Lily Pond

To ensure a professional experience we also created digital slides to act as an intro/lobby and outro for the event. The 16:9 digital copy was then reformatted into an equirectangular format for 360° viewing.

The deployment of the exemplar happened over a three-day period that included installation of technology/production elements, rehearsals and final live stream.

This allowed us to programme the lighting multiple times, adapting the settings to the most optimum settings for the cameras and the viewer experience.

Throughout the period the aql team and Eden I.T team were on hand to ensure network connection was at its optimum for data sharing between Meta cameras & TruCru for audio sync, lighting control and delivery of the final stream.

Final execution of the event went as well as could be expected, the choice of shots utilised TruCru's comms system to ensure audio & visual cues were synced for the event.

In all we invited approx. 150 people to view the live stream from a mixture of partners; DCMS and contacts in the music industry provided by Alice Boyd.

3.2 TESTBED DESCRIPTION – TECHNOLOGIES USED

5G NETWORK

aql partnered with the project to provide installation of a 5G network at Eden Project, Cornwall to help deliver accessible, understandable content such as storytelling, experiences, arts and performance.

To engage, not only the ‘connected generation’ but also allow connected nature to be delivered to care homes and support nature-as-therapy through virtual platforms. The network built by aql has helped Eden Project unlock real-time content to augment and reinforce its key environmental messages to a wider audience.

Installation in the form of a 360° 5G non-standalone (NSA) shared spectrum network consisting of:

- 3 x 4G 1800MHz and 3 x 5G 3.8-4.2 GHz antennas and Remote Radio Heads installed at the mast site
- 3 x 4/5G eNodeB/gNodeB/CPRI Base Band Units and associated router/firewall, switch and breakout equipment housed in a 42U network rack within the Eden Comms Room
- 1GB dedicated circuit connecting Eden to the Mobile Core within aql’s Data Centre
- Network connectivity in the Biomes using wireless access points.

The original planned 5G infrastructure for the project was a neutral host 5G NSA mobile network, connected to a dedicated 1GB/s internet connection and to aql’s mobile core in Leeds and London. aql would install and configure the network at site, including fixed network 5G connectivity to other consortium partners.

Unfortunately, aql was unable to deliver the planned 100MHz solution for the project as the kit was simply not available from the original supplier. 20MHz 5G equipment *had* been installed and was operational, although this did not give sufficient bandwidth to support the project exemplars.

aql were working with the supplier to begin testing 50MHz software in July 2021 and an upgrade to 100MHz would require a complete hardware swap-out. aql have been seeking resolution with the supplier however, due to contract/delivery issues between aql and said supplier, it was not feasible to swap out the 50MHz units to 100MHz throughout the life cycle of the project.

This meant that the project would move forward under a ‘plan b’ fibre network to deliver the remaining use cases. As the fibre network was designed as an interoperable system with the baseline 5G network, the testbed was still able to move forward with an alternative plan to offer increased bandwidth to cover that of the limited (50MHz) 5G installation - Installing core OS2 fibre links between the comms control room and strategic positions while implementing Wi-Fi access. Six access points were setup to facilitate network coverage, with bandwidth to support the META cameras and the associate exemplars.

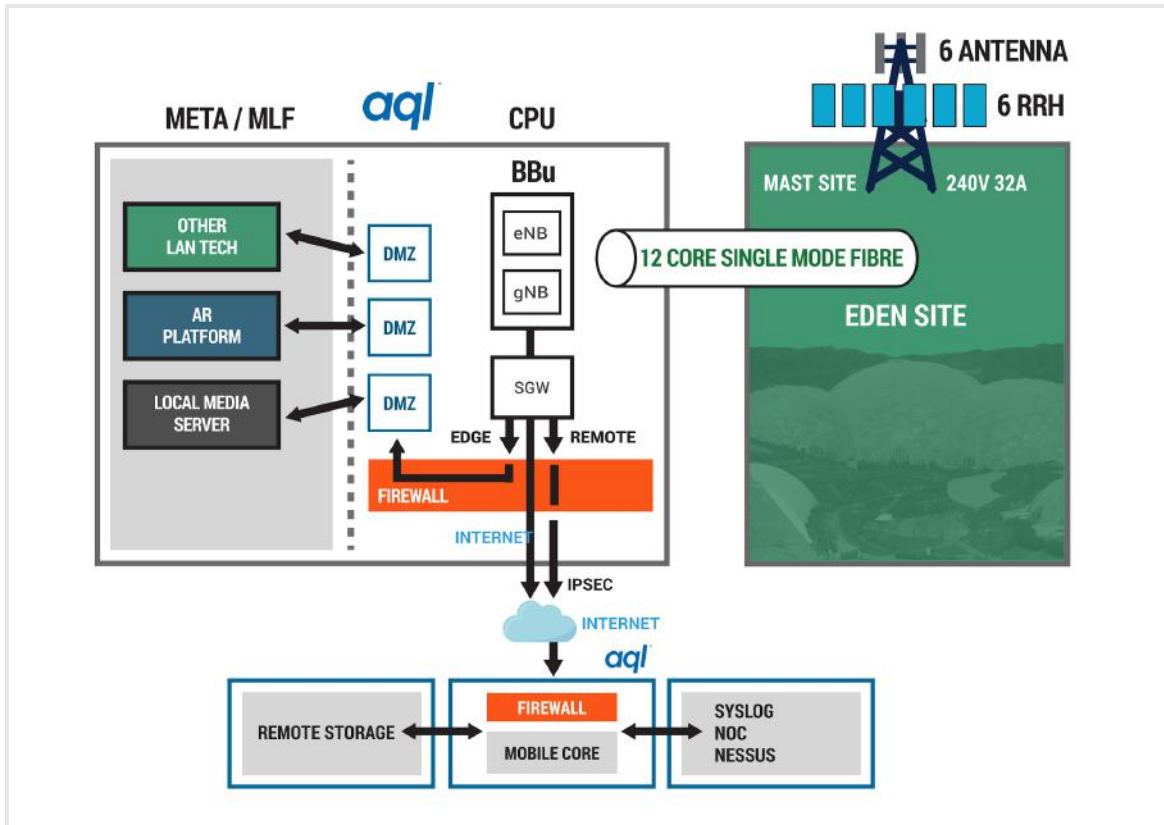


Diagram 1: High Level 5G Network Design

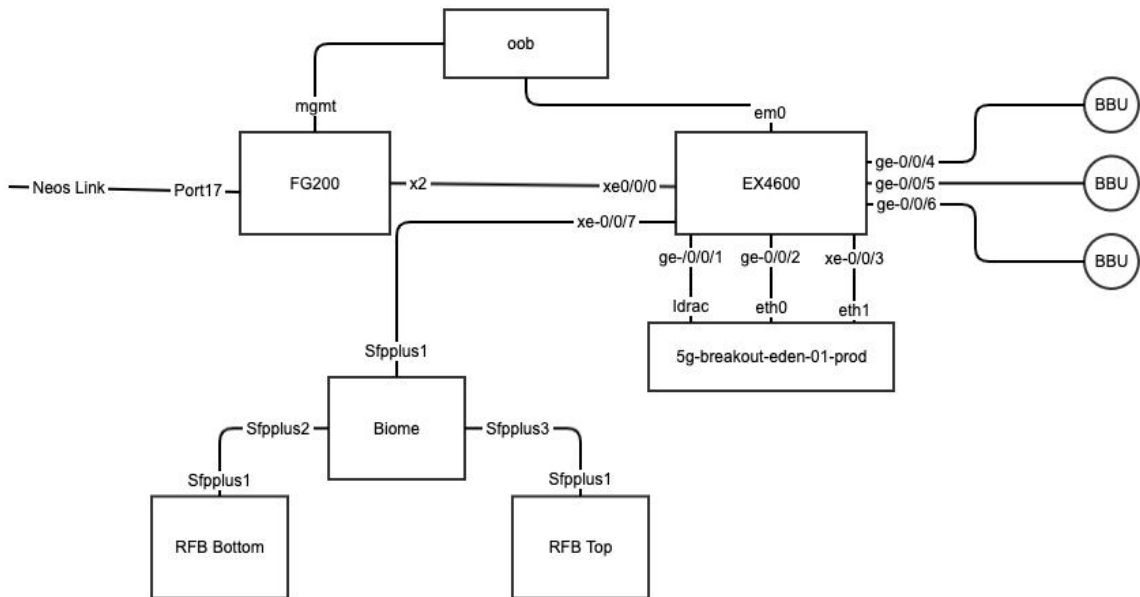


Diagram 2: Eden Network

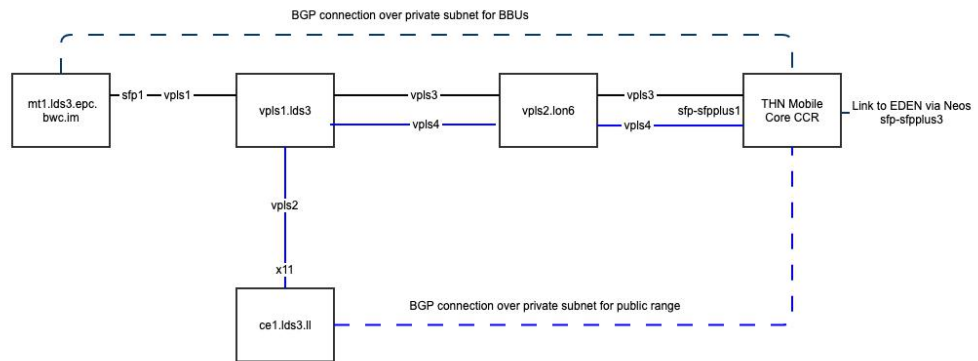


Diagram 3: Link to EdEN via Mobile Core

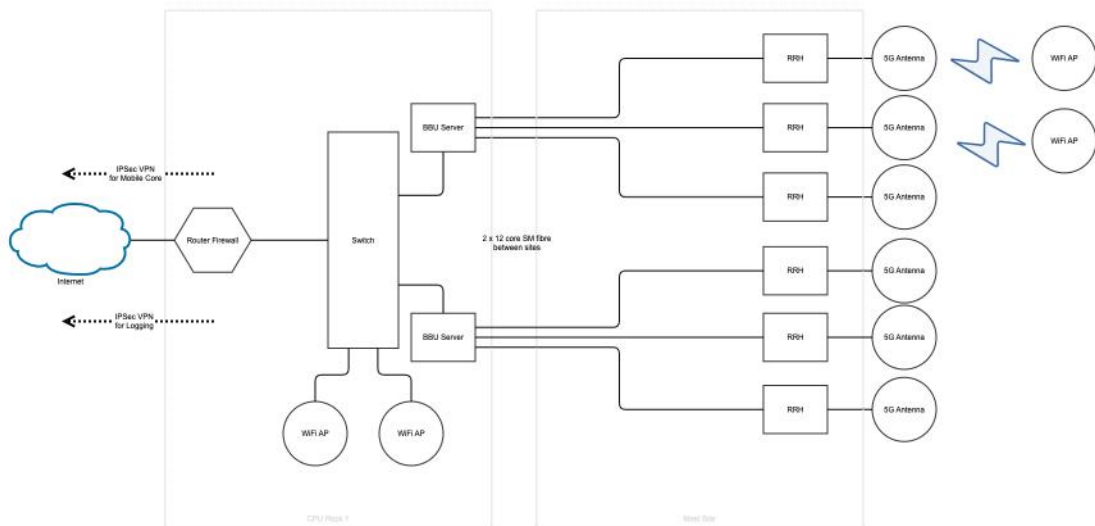


Diagram 4: EdEN Network Topology

Key parts of the site infrastructure are depicted in the EdEN Network Topology diagram above.

- Edge Firewall / Router

This will be a security device compatible with standard internet routing protocols, as well as having high firewall / IPS / threat protection throughput. The device will be the egress point from all internal networks, taking into account a policed ipsec connection back to the central mobile core for orchestration, sim access control and also other external egressing traffic flows.

- Top of Rack Switching responsible for:
 - Taking the handoff from sim cards attached to the RAN
 - Connection to sites with the EdEN infrastructure
- BBU Server

Part of the supplier infrastructure - this device operates the eNodeB & gNodeB as well as the CPRI

- RRH

Connected back to the BBU (Base Band Unit) over fibre and connecting to the Antenna in 2x2 MIMO over coax.

- Antennae (4G / 5G)

For both the 1800Mhz and 3600Mhz spectrums, we have different sets of Antenna. We will be using three sectors per mast site.

TRAFFIC FLOWS

i. Within the Mobile Core

The mobile core is made up of the following nodes:

- The Home Subscriber Server (HSS) component is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world i.e. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.
- The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.
- The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).

The mobile core is deployed in a HA mode (High availability) where each node is deployed on resilient infrastructure, with processes in place to automatically failover to backup nodes should a failure occur. All traffic is across a layer 2 / 3 domain within aqI/BlueWave Datacentres.

ii. Between Mobile Core and Base Station

As depicted in the diagram below:

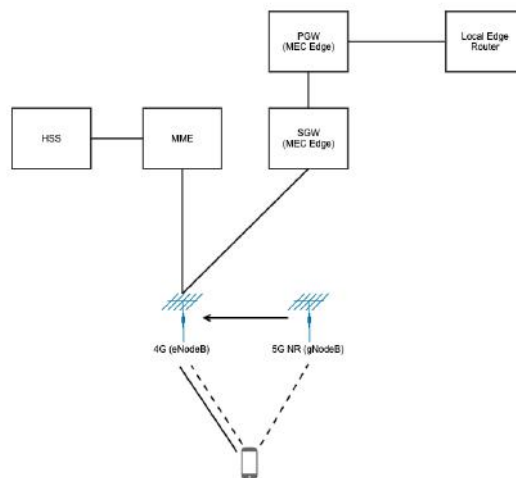


Diagram 5: 5G NSA

There is a communication channel between the eNodeB / gNodeB and the MME (Mobility Management Engine) - this will be over an IPSEC connection back to the mobile core located at aqI Datacentres. The profile will be based on the NCSC Prime recommendation (per <https://www.ncsc.gov.uk/guidance/using-ipsec-protect-data>) ensuring all traffic is fully encrypted.

Any data that egresses the local radio towards the MEC (Mobile Edge Computing) handoff will not itself be encrypted at the network layer - it will require the specific use case to use encryption where necessary at the application layer.

iii. Between a UE (User Equipment - i.e. *mobile*) and the MEC device

When a UE device wants to register and create a data session, the following requests/processes occur:

- UE creates an Attach Request to the eNodeB
- eNodeB makes attach request to the MME
- HLR authenticates request
- Session Request is made to SGW (Serving Gateway), and in turn the PGW (PDN Gateway)
- Attach is completed after RRC (Radio Resource control) configuration occurs

IoT Sensors and Dashboard

To assist Eden's drive to become carbon zero by 2023 and to provide an educational tool to better understand the relationship between rainforests and the climate, aql installed various sensors and built a data dashboard to provide learnings both onsite and to online participants.

The aql IoT core platform allows differing types of site sensors to provide live data for aggregation and reporting including IFTTT notifications. The platform allows sensors to connect through a variety of protocols including LoRaWAN, JSON Rest API, MQTT (Via 5G), and remote uploads through traditional file-based systems. The platform is API first allowing uploads to be processed through the aql IoT API.

The aql MQTT platform supports a variety of ways sensors can connect to upload information including Bluetooth, Wi-Fi and connected serial sensors. The Platform is API first and provides a detailed API Documentation Portal.

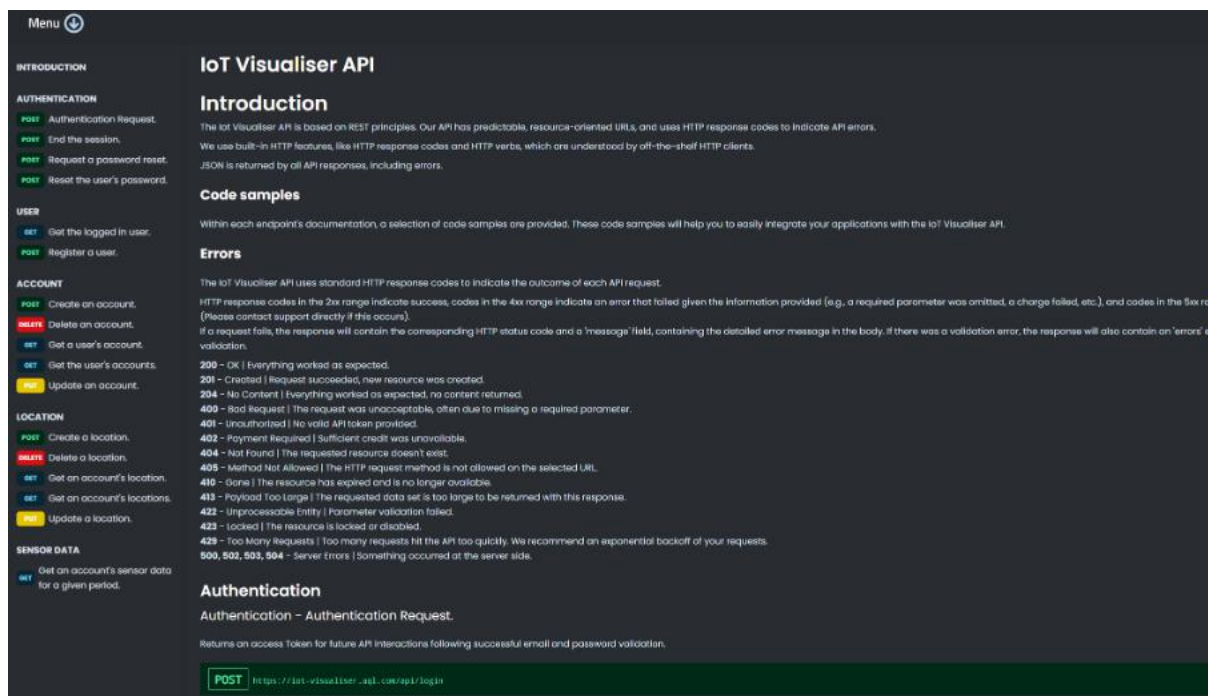


Image 53: Visualiser

Data can be reported on the <https://iot-visualiser-api.aql.com/api> allowing third party systems to view platform and data information. Additionally, the platform provides an access anywhere data portal which allows users to view all connected sensors across the differing connection routes. From within the platform a user can view the current readings, set alarms and warnings, and view historical data. This information can be fully accessed from the API as well. The API has been used by Eden to create variety of differing narratives with samples listed below.

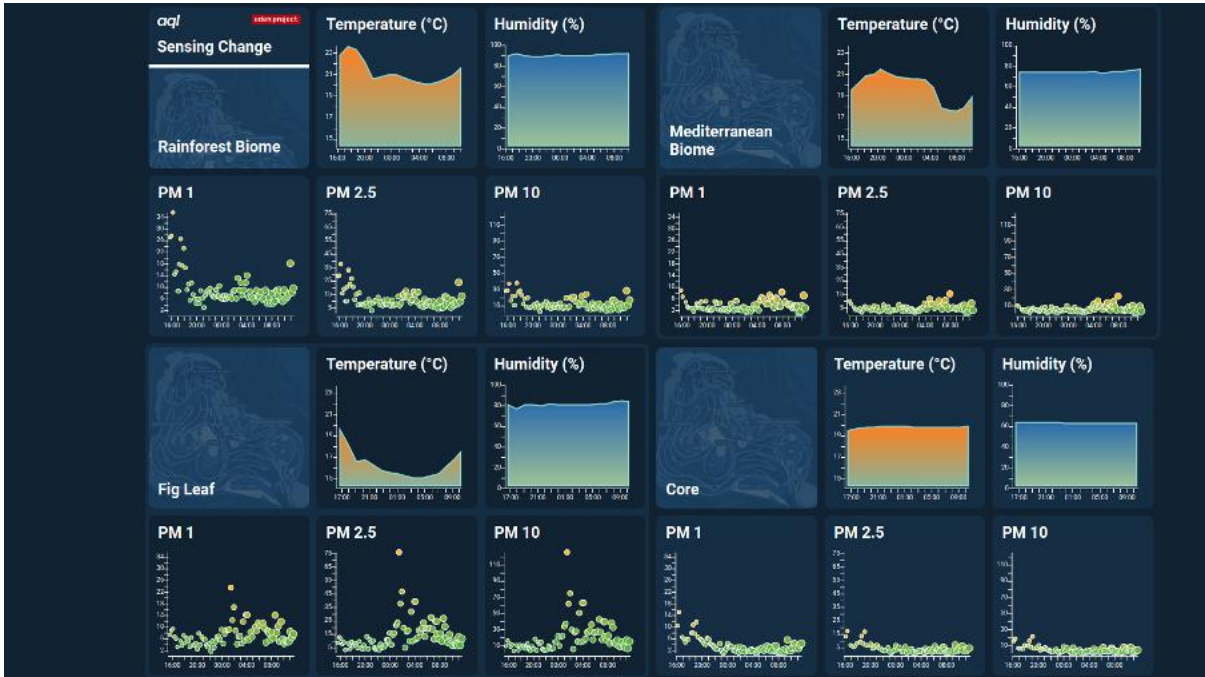


Image 54: The aql IoT Core Platform

Site Summary

The aql IoT Core Platform allows the Eden team to view all 5G enabled sensors across the differing biomes. Devices which return GPS Information are displayed within the Location Summary Page to provide an immediate view of the sensor Readings. From here a user can easily select a sensor and view its latest readings and be informed if any Sensors are currently reporting a state of alarm.

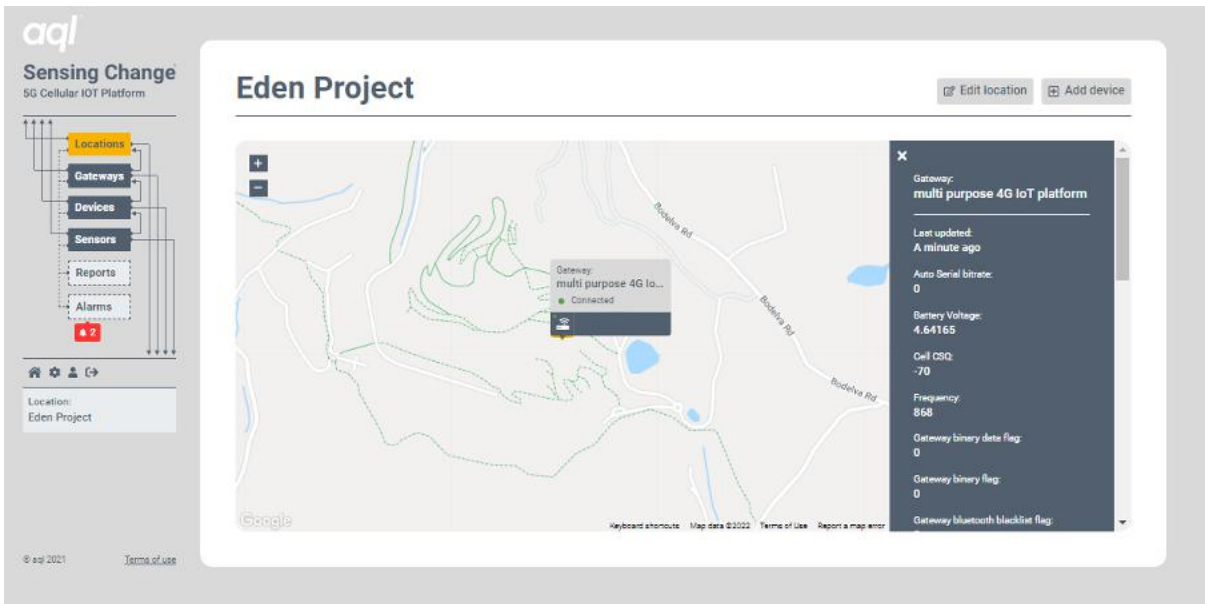


Image 55: Gateway Location

Environmental Analysis

The aql Core Platform is analysing a variety of 5G enabled sensors to provide the teams at Eden with current environmental analysis for reporting and site management.

Aranet BMS

The installed Building Management System has a variety of 5G sensors aiding the Eden team with key site information. Currently the following sensor types are installed:

Co2 Sensors

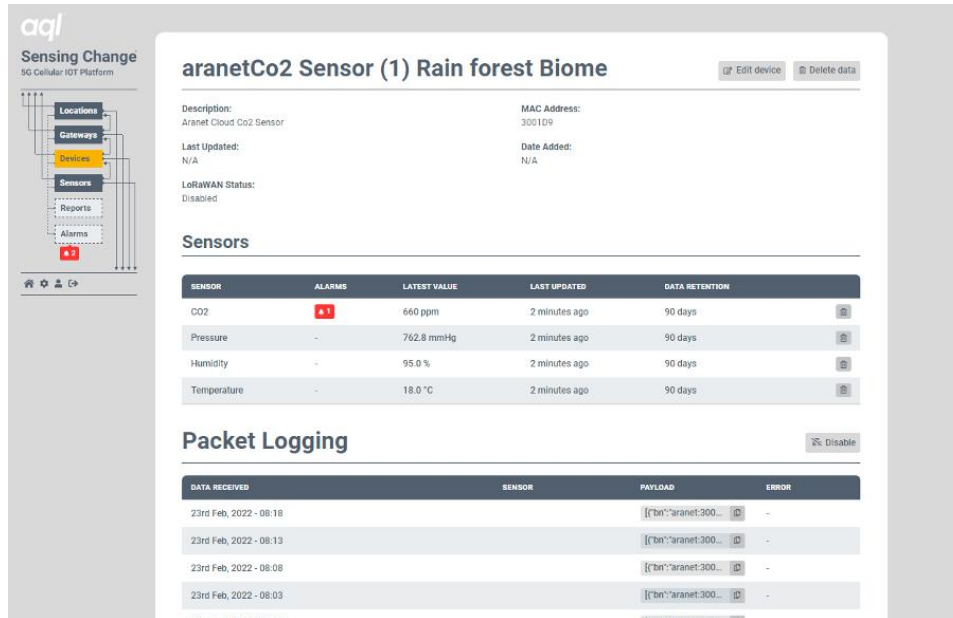


Image 56: CO2 Sensors

The aql IoT Core Platform allows the Eden team to set alarm values which will raise visual and email alarms when sensor readings achieve a specific reading. These alarms are clearly displayed within the alarms section or within the specific sensor summary page.

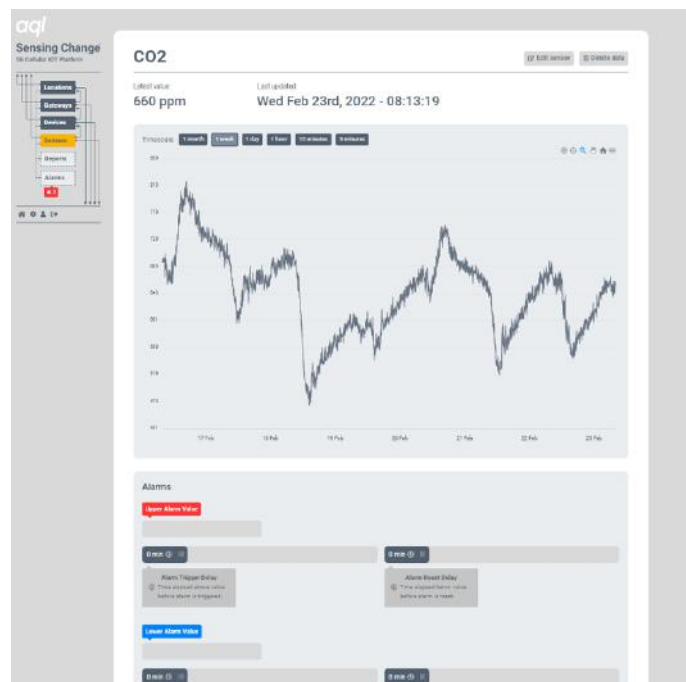


Image 57: CO2 Alarms

Temperature and Humidity Sensors

The screenshot displays the 'aranetemp Sensor (4) Outdoor Gardens' configuration page. On the left is a navigation sidebar with a tree view containing 'Locations', 'Gateways', 'Devices', 'Sensors', 'Reports', and 'Alarms'. The main content area includes:

- Header:** 'aranetemp Sensor (4) Outdoor Gardens' with 'Edit device' and 'Delete data' buttons.
- Description:** Aranet Cloud Temp Sensor. **MAC Address:** 100CAF.
- Last Updated:** N/A. **Date Added:** N/A.
- LoRaWAN Status:** Disabled.
- Sensors Table:**

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Temperature	-	7.2 °C	4 minutes ago	90 days
Humidity	-	97.0 %	4 minutes ago	90 days
- Packet Logging:** A section with an 'Enable' button and a table with columns 'DATA RECEIVED', 'SENSOR', 'PAYLOAD', and 'ERROR'. The table is currently empty with the text 'No data available.'

Image 58: Temperature and Humidity Sensors

The screenshot displays the 'Temperature' monitoring page. On the left is the same navigation sidebar as in Image 58. The main content area includes:

- Header:** 'Temperature' with 'Edit sensor' and 'Delete data' buttons.
- Latest value:** 7.2 °C. **Last updated:** Wed Feb 23rd, 2022 - 08:18:19.
- Timescale:** A row of buttons for '1 month', '1 week', '1 day', '1 hour', '15 minutes', and '5 minutes'. The '1 day' button is selected.
- Line Graph:** A line chart showing temperature fluctuations over a 24-hour period. The y-axis ranges from -0.05 to 17.05. The x-axis shows dates from 25 Jan to 22 Feb. The graph shows a clear diurnal cycle with peaks around 15°C and troughs around -0.5°C.

Image 59: Temperature Readings

Soil Sensors

aranetsoil Sensor (2) Edit device Delete data

Description: Aranet Cloud Soil Sensor MAC Address: 600451
 Last Updated: N/A Date Added: N/A
 LoRaWAN Status: Disabled

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Temperature	-	18.5 °C	1 minute ago	90 days
Volumetric water content	-	8.8 %	1 minute ago	90 days
Dielectric permittivity	-	5.360000000	1 minute ago	90 days
Electrical Conductivity	-	0.070000000 mS/cm	1 minute ago	90 days

Packet Logging

Enable

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
No data available.			

Image 60: Soil Analysis Sensors

Electrical Conductivity Edit sensor Delete data

Latest value: 0.070000000 Last updated: Wed Feb 23rd, 2022 - 08:23:19
 mS/cm

Timescale: 1 month 1 week 1 day 1 hour 15 minutes 5 minutes

The graph displays the Electrical Conductivity data over time, showing a relatively stable trend with minor fluctuations. The y-axis ranges from 0.000 to 1.280 mS/cm, and the x-axis shows dates from 25 Jan to 22 Feb.

Image 61: Electrical Conductivity from the Soil Analysis Sensors

A series of Soil Analysis sensors have been installed to provide the horticulture teams with immediate plant and soil analysis.

Air Quality Sensors

A series of 5G enabled LoRaWAN Air Quality Sensors provide environmental reporting and analysis. This information is available through the aql Core IoT Platform and has been used to create further Eden-specific data visualisations.

The screenshot displays the aql Sensing Change 5G Cellular IoT Platform interface. On the left is a navigation menu with options: Locations, Gateways, Devices, Sensors, Reports, and Alarms. The main content area shows details for a device named 'Long range wireless air quality monitor Fig & Leaf'. Below this is a 'Sensors' table and a 'Packet Logging' section.

Device Details:

- Description: Long range wireless air quality monitor
- MAC Address: 004057
- Last Updated: N/A
- Date Added: N/A
- LoRaWAN Status: Disabled

Sensors Table:

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Temperature	-	24.7 °C	1 minute ago	90 days
Relative Humidity	-	41.0 %	1 minute ago	90 days
Pressure	-	760.6 mmHg	1 minute ago	90 days
Battery Voltage	-	3.60 Vdc	1 minute ago	90 days
VOC's	-	2 ppm	1 minute ago	90 days
mc_pm1_0	-	1 µg/m3	1 minute ago	90 days
mc_pm2_5	-	3 µg/m3	1 minute ago	90 days
mc_pm4_0	-	5 µg/m3	1 minute ago	90 days
mc_pm10_0	-	6 µg/m3	1 minute ago	90 days
CO2	-	441 ppm	1 minute ago	90 days
CO2e Estimate	-	1163 ppm	1 minute ago	90 days
Indoor Air Quality	-	116 /500	1 minute ago	90 days

Packet Logging: No data available.

Image 62: Air Quality Sensors

Environmental Impact Analysis

To support the Eden Team with environmental analysis, a selection of business metrics is managed within the aql core IoT Platform. To support the automated delivery of this information the programme saw the development of secure data uploads so the Eden team can upload the information in near real time for immediate management and analysis.

These Include:

Meat Free Meals

aql Sensing Change
5G Cellular IOT Platform

Meat Free Meals [Edit device](#) [Delete data](#)

Description: Eden meat free meals MAC Address: MeatFree

Last Updated: N/A Date Added: N/A

LoRaWAN Status: Disabled

Upload Readings

Please select a CSV file to upload:

[Select a file](#)

[Upload](#) [Upload history](#)

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Meat	-	277	22nd Oct, 2021 - 00:00	90 days
Meat Free	-	183	22nd Oct, 2021 - 00:00	90 days

Packet Logging [Disable](#)

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
23rd Feb, 2022 - 09:52		10	-

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Image 63: Meat Free Meals

Trade Waste

aql Sensing Change
5G Cellular IOT Platform

Trade Waste [Edit device](#) [Delete data](#)

Description: Eden trade waste MAC Address: EdenTradeWaste

Last Updated: N/A Date Added: N/A

LoRaWAN Status: Disabled

Upload Readings

Please select a CSV file to upload:

[Select a file](#)

[Upload](#) [Upload history](#)

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Trade Waste Weight	-	0 kg	1st Apr, 2020 - 00:00	90 days

Packet Logging [Disable](#)

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
23rd Feb, 2022 - 09:26		233	-

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Image 64: Trade Waste

Metal Waste

aqi
Sensing Change
5G Cellular IoT Platform

Metal Waste Edit device Delete data

Description: Eden metals waste MAC Address: EdenMetalsWaste

Last Updated: N/A Date Added: N/A

LoRaWAN Status: Disabled

Upload Readings

Please select a CSV file to upload.

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Metals Waste WEEE	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Fridge Freezer	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Copper	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Iron Mixed	-	0.76 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Aluminium	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Batteries Lead Acid	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Nicad Battery	-	0.00 t	23rd Apr, 2022 - 00:00	90 days
Metals Waste Mixed Dry Batteries	-	0.00 t	23rd Apr, 2022 - 00:00	90 days

Packet Logging Disable

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
23rd Feb, 2022 - 08:38		-	-

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Image 65: Trade Waste

Recycling

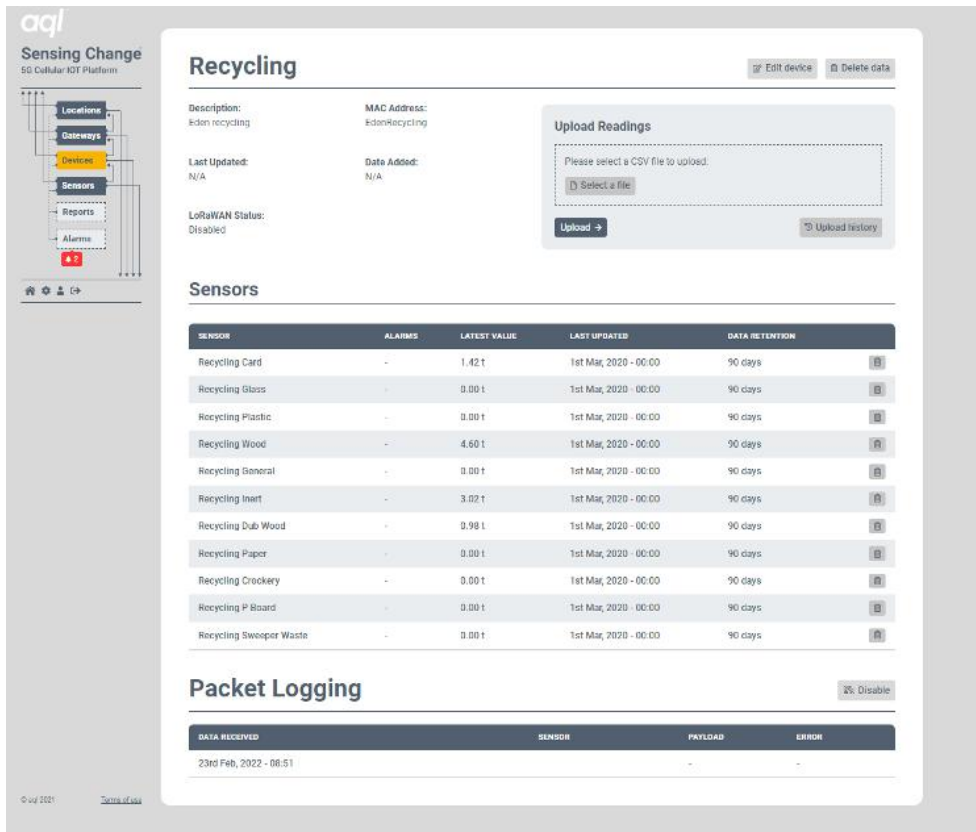


Image 66: Recycling

Food Waste

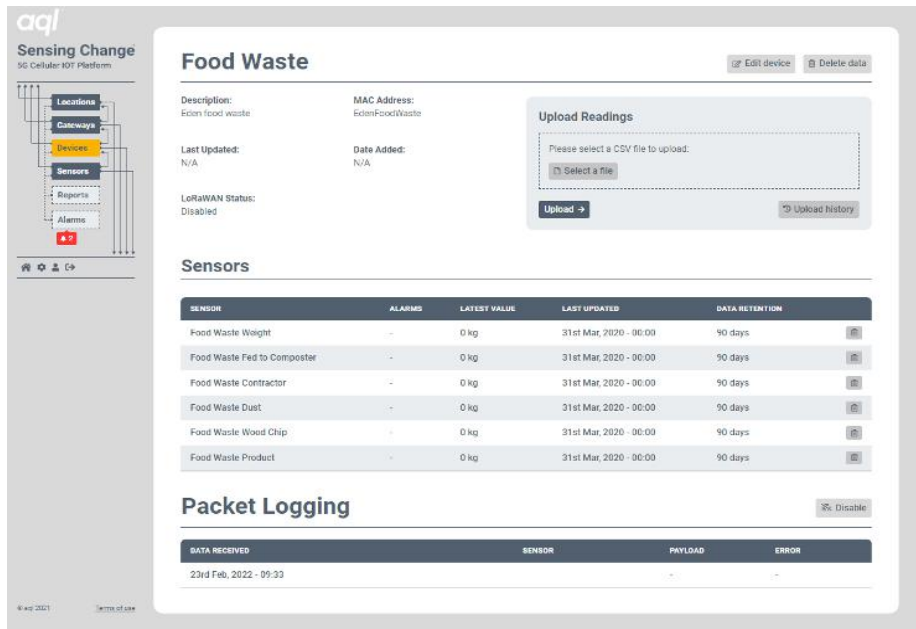


Image 67: Food Waste

Pledges

aql Sensing Change
5G Cellular IoT Platform

Pledges Edit device Delete data

Description: Eden pledges MAC Address: Pledges

Last Updated: N/A Date Added: N/A

LoRaWAN Status: Disabled

Upload Readings

Please select a CSV file to upload.

Select a file

Upload Upload history

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Pledge Busy	-	2306	7 minutes ago	90 days
Pledge Care	-	2812	7 minutes ago	90 days
Pledge Compost	-	2637	7 minutes ago	90 days
Pledge Eat	-	3142	7 minutes ago	90 days
Pledge Grow	-	2923	7 minutes ago	90 days
Pledge Recycle	-	2974	7 minutes ago	90 days
Pledge Reduce	-	2238	7 minutes ago	90 days
Pledge Repair	-	2247	7 minutes ago	90 days
Pledge Reuse	-	2537	7 minutes ago	90 days
Pledge Share	-	2270	7 minutes ago	90 days
Pledge Total	-	25486	7 minutes ago	90 days

Packet Logging Disable

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
23rd Feb, 2022 - 09:48		25486	-

Image 68: Pledges

Energy Monitoring

To provide the Eden teams with energy usage information, a variety of smart IoT enabled data loggers have been installed. These data loggers are then providing data exports to the aql core IoT Platform for data reporting and analysis allowing the differing teams to manage energy statistics across Eden.

aql Sensing Change
5G Cellular IoT Platform

Meter Readings Edit device Delete data

Description: Eden meter readings **MAC Address:** EdenMeterReadings

Last Updated: N/A **Date Added:** N/A

LoRaWAN Status: Disabled

Upload Readings

Please select a CSV file to upload:

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
Meter Readings Total Ground & Rain Water	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings HTB Rainwater (DB)	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Total Harvested Groundwater (DB)	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Core Solar Elec (DB)	-	0.000000000 kWh	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Core Total Gas (DB)	-	0.000000000 kWh	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings WTB Irrigation (DB)	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Main Elec (Stark)	-	0.000000000 kWh	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Main Water (DB)	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings East Gate Main Water (DB)	-	0.000000000 m3	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Warehouse Solar Elec (DB)	-	0.000000000 kWh	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>
Meter Readings Workshop Solar Elec (DB)	-	0.000000000 kWh	17th Feb, 2022 - 23:30	90 days <input type="button" value="m"/>

Packet Logging Disable

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
No data available.			

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Image 69: Energy Monitoring

Visitor Monitoring

To provide the Eden team with an understanding of visitor flow, several aql Edge Gateways are being used to listen for specific Bluetooth Beacon addresses, these gateways will register a beacon ping with a supplied RSSI, allowing the aql core IoT Platform to provide flow density across the differing monitored locations.

Visitor Flow Gateways

Gateways Add gateway

Filter Gateways

Location: Eden Project Reset

GATEWAY	ALARMS	LOCATION	CONNECTION STATUS	DEVICES	SENSORS	FIRMWARE
aql gateway 2	-	Eden Project	Connected	0	26	v 1.0.0
aql gateway 3	-	Eden Project	Connected	0	26	v 1.0.0
aql gateway 7	-	Eden Project	Connected	0	26	v 1.0.0
Eden Demo Virtual Gateway	-	Eden Project	Connected	1	32	v 1.0

Image 70: Visitor Flow Gateways

BLE Beacon Visitor Pings

Beacon 1 Edit device Delete data

Description: FSC-BP108 Proximity Sensor **MAC Address:** DCCDDAEE3813

Last Updated: N/A **Date Added:** N/A

LoRaWAN Status: Disabled

Sensors

SENSOR	ALARMS	LATEST VALUE	LAST UPDATED	DATA RETENTION
rssi	-	-92	5 seconds ago	90 days

Packet Logging Enable

DATA RECEIVED	SENSOR	PAYLOAD	ERROR
No data available.			

Image 71: BLE Beacon Visitor Pings

360° CAMERAS

The project features a total of nine custom built Meta Cameras, six of these cameras are in the Rainforest Biome, one in the Mediterranean Biome and two are 'roaming cameras' that can be placed anywhere they can obtain a signal.

The map below shows our original plan for the camera locations, it holds true to where they have finally been installed.



Image 72: Map overview of camera placements

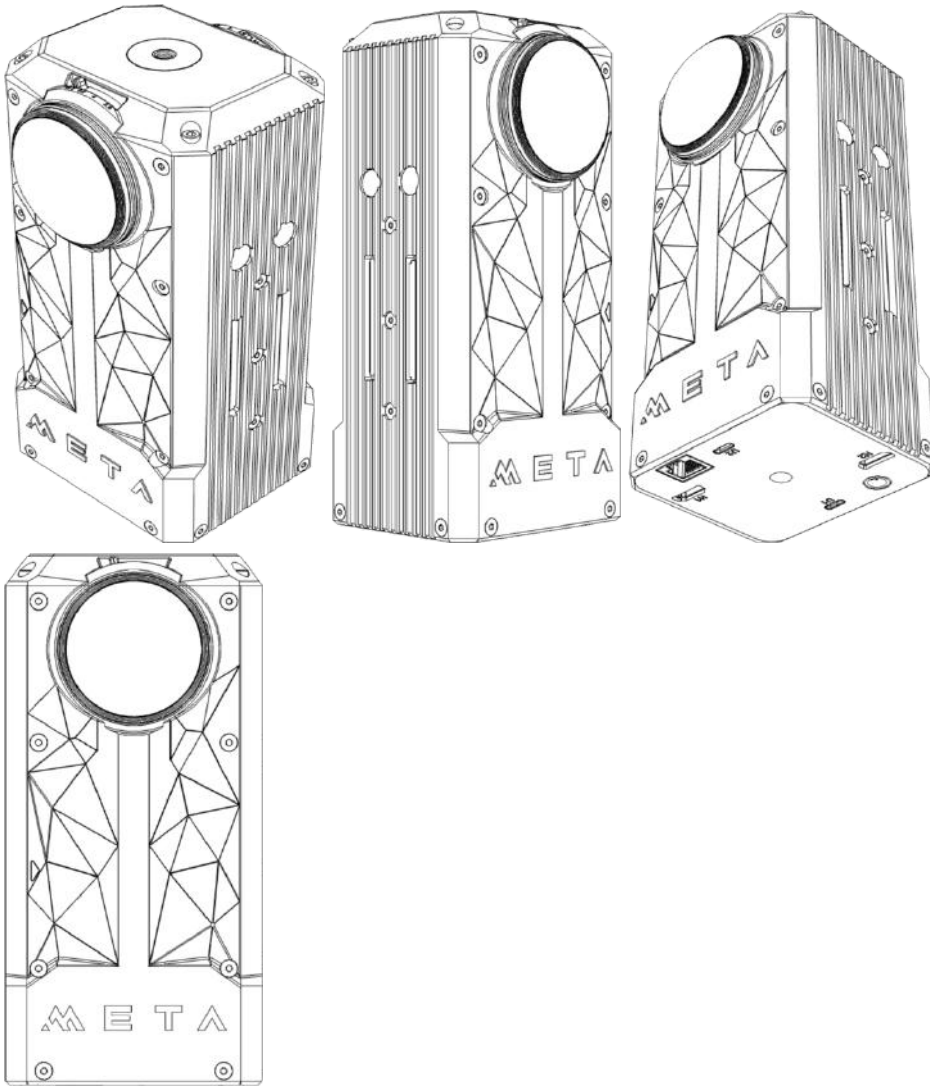


Image 73: Wireframe representations of Meta 2 camera design



Image 73: Meta 3 “lookout” cam placement

Cam. 1 ‘Lookout’:

This camera is the biggest achievement for META on the project, it is a one of a kind ‘Meta Three’ high resolution camera. It has the potential to capture content up to 12.5K resolution. The camera is based on a 4 lens/sensor system, each of which is 6K. The camera is slung upside down, under the lookout platform, over the top of the rainforest, giving a panoramic view.

The camera is currently connected to the Eden Network via ethernet cable to the nearest AP. Data is taken back to the server room where it is combined/stitched together in to a single seamless 360° video stream on one of the Meta Camera work stations. This work station then pushes the stream to MLF’s servers where the data layer is overlaid before being pushed out for incorporation in to the Eden Universe Platform.

One of the objectives of the lookout camera was to have overlaid AR live data visualised through the Eden Universe virtual platform. This meant it needed to be completely stable for the data to be correctly positioned over the feed. One of the issues we found was that the entire platform shakes when people walk on it or even just with wind over the biome. As such we needed to develop a form of live stabilization to the camera.

Stabilization was eventually achieved by the addition of an active gimbal placed between the camera and the mounting point to the platform. This could correct for platform shakes, yaws, pans and tilts but of course can do nothing for large horizontal ‘shears’ of the platform. This though is enough for the purposes of this use.

Cam. 2 - South East Asia House

This camera is a standard Meta Two, mounted on a pole, out of the reach of the public and connected to the broader network via ethernet connection. It follows the standard pipeline of Meta Two for capture, offloading via ethernet to the AQL network, back to the Meta Camera servers for stitching and streaming out to the Eden Universe.



Image 74: Meta 2 vertical camera

Cam. 3 - Vertical Camera

This camera is another that has been a huge achievement for us on this project. The camera travels continuously up and down the length of a tree and above the rainforest canopy while streaming in 360°. The camera is a Meta Two with an additional custom 'Wi-Fi bridge' mounted internally. This Wi-Fi bridge connects directly to the nearest wireless access point without dropping signal or quality throughout its range of travel.

From this point the data follows the standard pipeline of traveling back to the Meta Camera servers for stitching and streaming out to the Eden Universe.

One of the key features of this system is the winch, mounted on the roof of the Biome, it not only pulls the camera up and carefully lowers it, but also powers the camera by utilising the same cable that pulls the unit to also power it. The winch itself is connected to the network over DMX which is converted to ethernet and then fed to the nearest Access Point. The winch is running a constant loop on a program that resets every morning at 5am. Its approximately 2.5-minutes up and 2.5-minutes down.

The camera is maintained in its position by two 'guide ropes' that run either side of the camera. These ropes and the rollers on the sides of the camera, seen in the picture above, were designed to fit into the blind spot between lenses. By positioning the guide ropes like this they are not visible to the viewer in the live streams and are completely invisible.

A large issue that was found with the vertical camera was the oscillations that it would have as it travelled up and down its trajectory. This led to a shaky live stream and poor-quality imagery. A number of iterations of 'active gimbals' and passive stabilisers were tried to mitigate the issue, along with changing the material of the guide ropes and greatly increasing their tension. Despite all of

these efforts a far simpler solution was eventually found - the complete loosening off of the cables (to the point of slackness) almost completely mitigated the oscillations.

Footage from this vertical camera is used in conjunction with an augmented reality layer provided by project partner MLF to make the 'Weather Maker' experience.



Image 75: Meta 2 Horizontal camera

Cam. 4 - Horizontal Camera

This camera is another that has been a huge achievement for us on this project. The camera travels continuously along the length of wires horizontally strung through a large part of the rainforest biome.

The picture above shows the 'Infinity Drive', a system that Meta Camera custom designed and built for the Eden Universe testbed to carry the camera along the wires.

The unique aspect of this system is that there is no need for a battery to power the camera or the infinity drive. Rather, the power is fed along the cables themselves

As with the vertical camera, the horizontal camera has an internal wireless bridge fitted, through which it can connect to the nearest wireless access point and from there transfer to the network.

In the initial version of this system, steel cables were used which were great for rigidity and strength but the current drop-off along the length of the cable was too great, meaning the Infinity Drive was coming to a stop.

To maintain consistent power throughout the length of travel we had to replace the cables custom-made copper core cables, these allowed the full length of travel whilst maintaining power in the camera too.

Similar to the Meta 3 and vertical camera, this unit has had an issue with movement causing a juddering motion along the route. So that the camera can be effectively used as part of the projects future plans, the Infinity Drive is being redesigned to mitigate this issue.



Image 76: Meta 2 Lily pond camera

Cam. 5 - Lily Pond

This camera is a standard Meta Two, mounted on a pole, out of the reach of the public and connected to the broader network via ethernet connection. It follows the standard pipeline of Meta Two for capture, offloading via ethernet to the AQL network, back to the Meta Camera servers for stitching and streaming out to the Eden Universe.

In this picture above you can see the camera is mounted close to the sprinkler and above it. This sprinkler has a horizontal throw of water, meaning we can safely avoid water directly hitting the device.



Image 77: Meta 2 Lily pond camera

CAM 6: Market Cam

This camera is a standard Meta Two, mounted on a 6m pole, out of the reach of the public and connected to the broader network via ethernet connection. It follows the standard pipeline of Meta Two for capture, offloading via ethernet to the AQL network, back to the Meta Camera servers for stitching and streaming out to the Eden Universe.

This camera was the first to get some unwanted covering from the birds at Eden, with them perching on top and then defecating on to the lenses. Bird faeces is particularly bad for paint surfaces, let alone lens surfaces so this is a problem for the longevity of the cameras at Eden. We have suggested attaching spikes to the tops of the cameras, this is a technique often used to stop the perching of pigeons in towns and cities.

Cam. 7 - Mediterranean Biome

This camera is a standard Meta Two, mounted on a pole upside down from an aerial footbridge over the top of the Med Biome. It is out of the reach of the public and connected to the broader network via ethernet connection. It follows the standard pipeline of Meta Two for capture, offloading via ethernet to the AQL network, back to the Meta Camera servers for stitching and streaming out to the Eden Universe.

Cams. 8 & 9 - Roaming

Cameras 8 and 9 were Meta Two units designed as roaming options that would be installed on tripods and deployed around the grounds to talk through either the 5G network or wired access points.

CAMERA WORKSTATIONS

All of the data shred by Meta Cameras are fed back, via the AQL network, to the workstations in the server room. Each of the cameras has a dedicated "INSERT MAKE / MODEL OF" workstation, these are all based in a single rack.

Once the streams reach the workstations they are received and decoded by the 'Meta Stitcher', this takes out the distortion from each of the lens' streams and blends them together in one seamless 360° video. This stream is then fed to OBS via NDI and combined with a pre-recorded audio stream before being streamed out to the Eden Universe.

For the lookout camera, the stream is passed via NDI to the MLF servers where it is combined with the live data overlays and then fed back to the Meta workstation.

Future Connections and 5G

The cameras are ready to have their existing connections swapped out when the aql 5G network comes online. At this point aql will provide small 5G modules that will plug-in to the ethernet ports of the cameras and allow for continuation of services over the next generation network.

AUGMENTED REALITY (AR)

Over the period of the testbed the partners have undertaken a full-stack method and implementation processes to develop a number of ‘Proof of Concept’ (POC) systems required to build the “Invisible Engine” that would be required to deliver the proposed AR experiences.

Over the course of the 5G Create Project, unique deployments have been designed and developed, implementing a variety of technologies and techniques all designed to leverage the power of 5G networks and their capabilities. At the core, the Eden Rainforest Biome was networked utilising the latest in high-speed connectivity to enable all four exemplars. A new fibre backbone to the wider world and the latest in 5G and W-Fi 6 infrastructure were embedded into the biome, allowing unprecedented connectivity enabling MLF to operate in a relatively unimpacted manner.

These core systems were based on the understanding of the narrative tools required by each exemplar, in discussion with the consortium and through the designed “one system, multiple output” approach originally specified in the schematic design

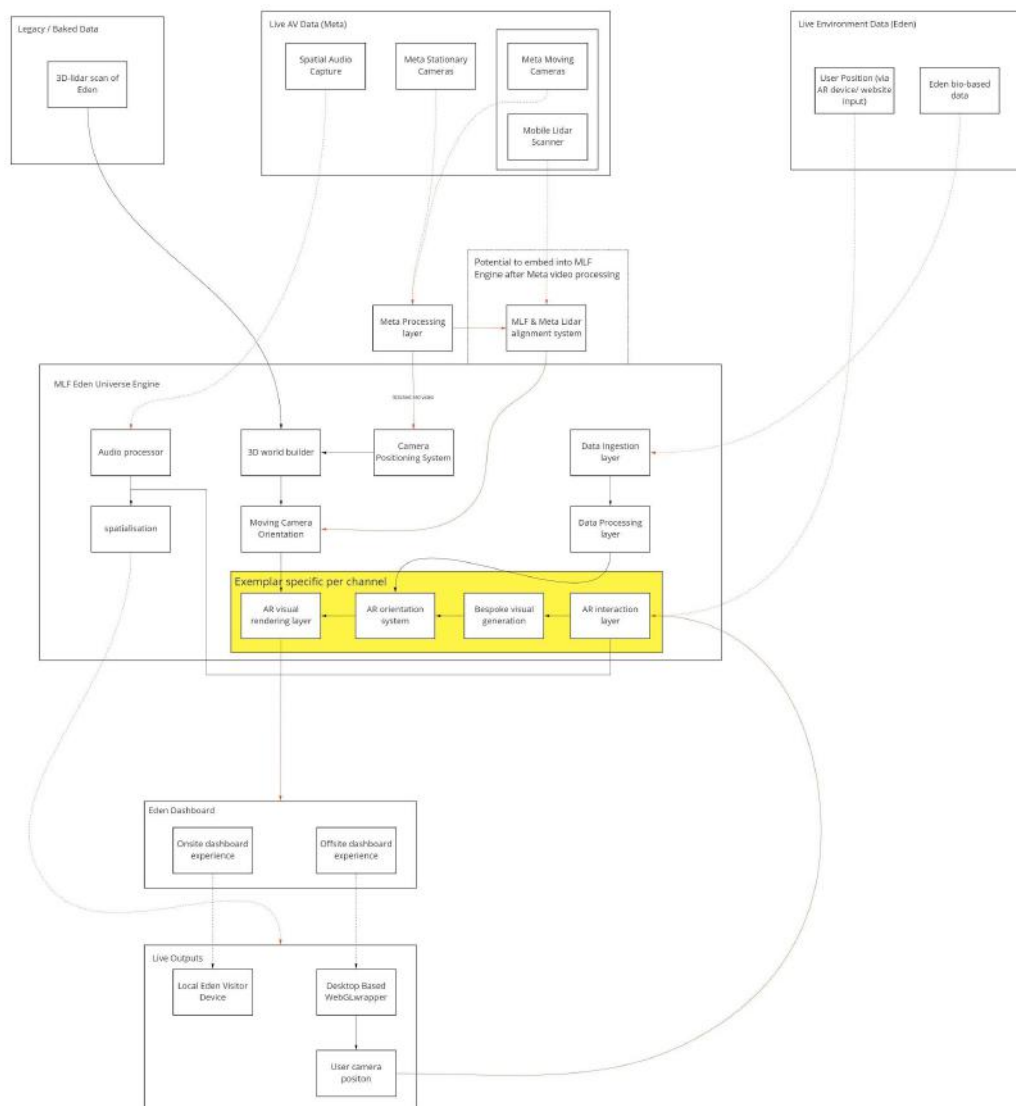


Diagram 6: “Invisible Engine” Core technical architecture

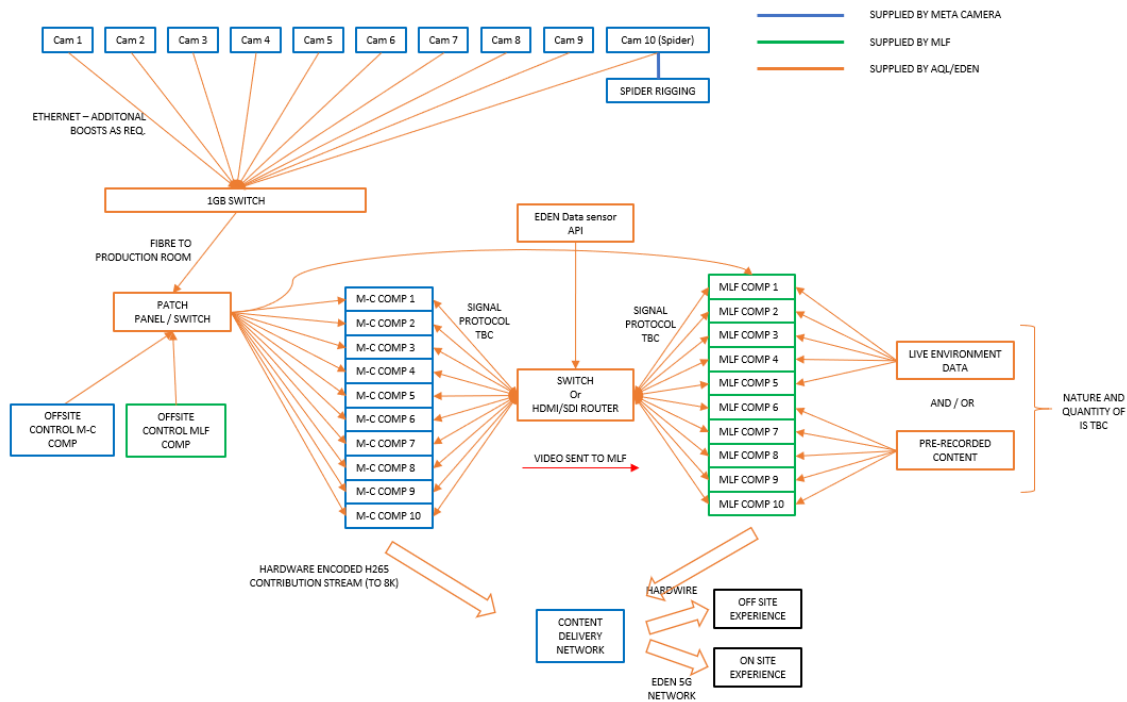


Diagram 7: Networked Infrastructure technology stack

There have been three exemplars that have utilised the most unique aspect of the project and the ultimate purpose of the proposed integration of 5G infrastructure – Visitor Experience, Education and Health & Wellbeing.

Utilising the live stream feeds from the Meta cameras spread around the biome and a variety of onsite AR devices (iPad Pro tablets), partner MLF helped design, develop and implement a unique AR experience; “The Invisible Rainforest”. Developed as both an on-site hand-held experience and off-site online experience The Invisible Rainforest explores the process of oxygen creation, carbon capture and the natural processes in between a combined scientifically accurate and visually stunning environment. Either utilising and augmenting the live 360° camera footage with mapped overlays of the hidden systems working within trees, soil and plant or directly over the top of the real flora when onsite, the system runs in real-time to take the live feed from the cameras, work out the position and orientation of the footage of the camera, and overlays the animated AR layers that highlight different parts of the carbon sequestration process all powered by data gathered in real-time via newly embedded and enabled sensors and readings. In the handheld experience, all footage seen is generated entirely in real-time and streamed to the user's devices in a method known as render streaming, enabled only by the ultra-high bandwidth capacity of the installed network.

A unique narrative journey was developed in conjunction with Eden’s lead storytellers allowing onsite visitors to explore the whole biome at a number of different levels of detail, starting in the sky looking over the whole space, eventually working down to the specific fine details within unique hero trees within the biome.

To facilitate off-site users, a bespoke website interface was developed in collaboration with 3DeepMedia, it incorporates the same narrative journey as the on-site story, but in a unique web-based interface, that directly connects to the live streams of the 360° cameras, including a mixture of raw feeds and those with AR layers.

This web infrastructure and onsite narrative AR experience form the backbone of these exemplars.

OVERVIEW TECHNOLOGIES USED

All of the above elements have then fed into the overall Universe Network map for delivery of the use cases and to build a foundation for the legacy aspirations of the project.

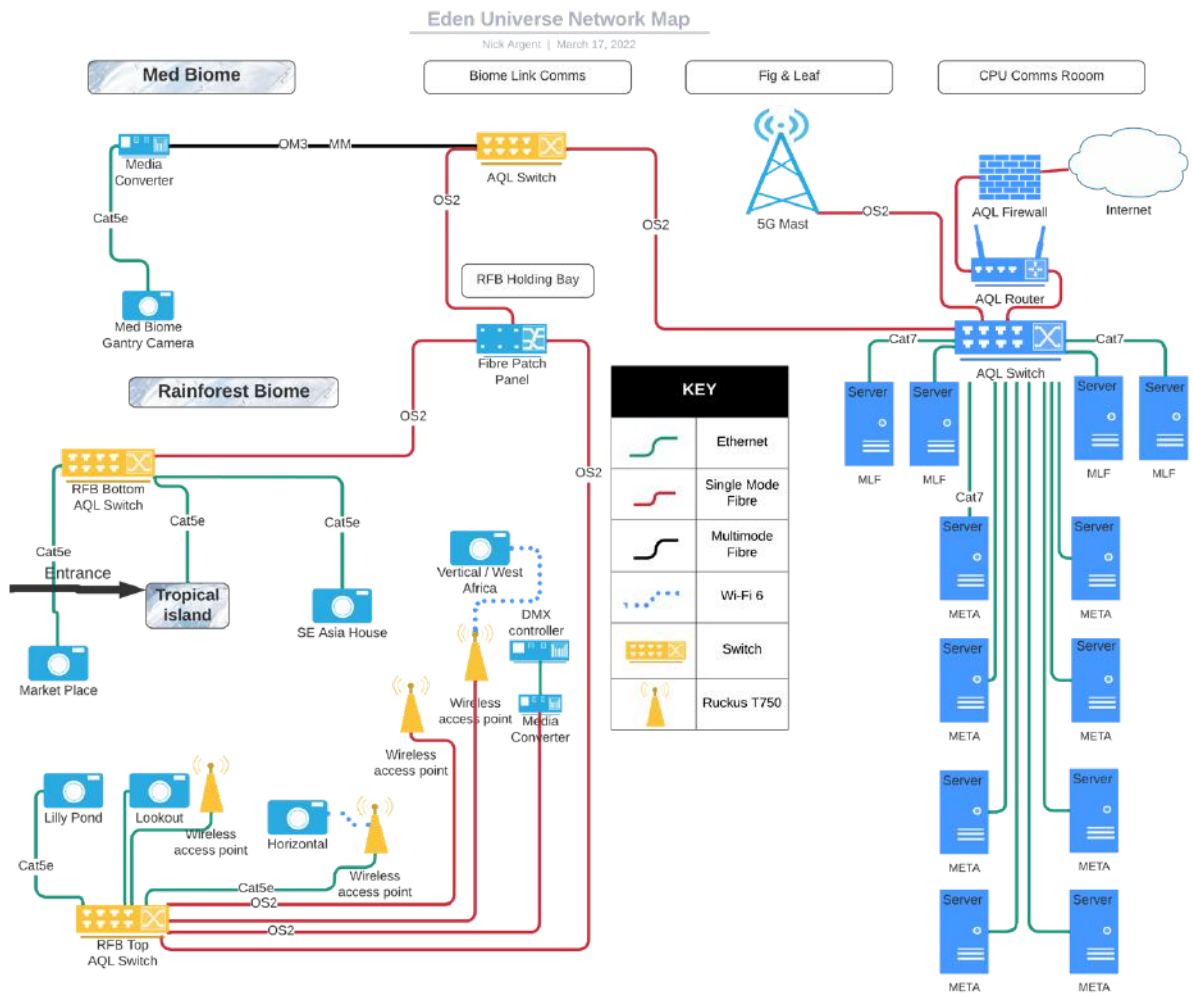


Diagram 8: Eden Universe Final Network Map

3.3 DESCRIPTION OF TESTBED – APPROACH TO SECURITY

Under the guidance of the Security Working Group (SWG) led by aql's Professor Adam Beaumont, and following the projects Security Strategy In addition to ISO27001 practices, the Eden Universe has adopted a defence-in-depth, secure-by-design approach applied to the end to end design of the project, use cases, infrastructure design and implementation, along with the software controls within the application, network and radio layers. A summary of layered risks and mitigations were demonstrated.

4. DESCRIPTION OF RESULTS

Use case (exemplar) metrics

Together with the team at DCMS we agreed a number of metrics for each Exemplar to demonstrate impact. These were recorded in the 'Benefits Realisation' (BR) document. The majority of data collected was quantitative and where appropriate it also included an element of qualitative.

Methodology

We developed a range of surveys to collect data for the agreed metrics. These surveys were designed to suit the capabilities of each exemplar audience*. Along with the core BR metrics, we also included a range of questions to help provide an understanding of how the various elements of exemplars were received by trial participants. These were designed to uncover insights to inform product enhancements of the experience(s) if necessary.

Baseline data was taken from Eden's ongoing 'visitor exit survey' covering the time period 4-weeks w/c 17 May 2021. At the time of agreeing baseline results with DCMS it was highlighted that while baseline data could not be comparable for each exemplar they could be used as a guide only.

For Exemplar: Health & Wellbeing, we worked with Plymouth University who provided the technology for 1 of the 3 Care Homes taking part in the trial, as well as leading the evaluation to monitor impact. For the collaboration with Liverpool's Rowan Garth Care home, Eden led the evaluation.

*we had to ensure the design of each Exemplar survey would be suitable for each audience especially: Health & Wellbeing: elderly in care homes – simple, minimal questions and Education: consideration of age range of pupils – simple, clear, minimal questions

Use case (Exemplar) trails evaluation: methodology summary

Exemplar	Audience	Trial period	# of participants	Approach	Location
'Invisible Rainforest' journey through Eden's Rainforest Biome	Visitors	Nov'21-Jan'22	58	Face-to-face digital survey & discussion	The Eden Project, Cornwall
'Self-led' journey through Eden's Rainforest Biome	Visitors	Nov '21 – Jan '22	52	Face-to-face digital survey & discussion	The Eden Project, Cornwall
Education	Teachers & Pupils	Dec '21			Schools in Cornwall x 4
Health & Wellbeing	Elderly residents in Care Home(s)	Nov'21 – Jan '22	24	Plymouth University led evaluation: paper surveys and staff/participants discussions	Care Homes, Cornwall x 3

Health & Wellbeing Collaboration	Elderly residents In Care home	Feb-March '22	Ongoing	Paper based surveys Staff observations captured throughout the trial	Care Home, Liverpool
Arts & Culture	Online	Jan '22	38	On-line survey	On-line
Virtual Tour	Online	Dec '21-Mar '22	96	On-line survey	On-line

Exemplar: Visitor Experience - Virtual Tour

Audience: on-line via The Eden Universe Platform

Feedback

Following their Virtual Tour, visitors were invited to provide feedback via an online survey. A button 'Take the Survey' was prominent on the screen throughout the VT experience.

Description of results

Nearly 9 in 10 rated the experience positively (88%). For 7 in 10, it provided them with a connection to nature. *"Its as if I'm in an actual rainforest, all senses are alive"*

For many it was a very engaging experience; 79% said it was absorbing and held their attention. In the words of some viewers:

"Visually compelling, easy to move around and intuitive interaction"

"Sound was great, visually stunning"

"Great idea to connect people with the nature world like this virtually"

"Who doesn't like important facts and figures presented in a clear and interesting way!"

"Excellent visual effects and very informative"

"I feel like it has reminded me of the beauty of nature and the importance of preserving it"

"High quality camera"

Most viewers (87%) felt they had knowledge of the Rainforest prior to the VT experience.

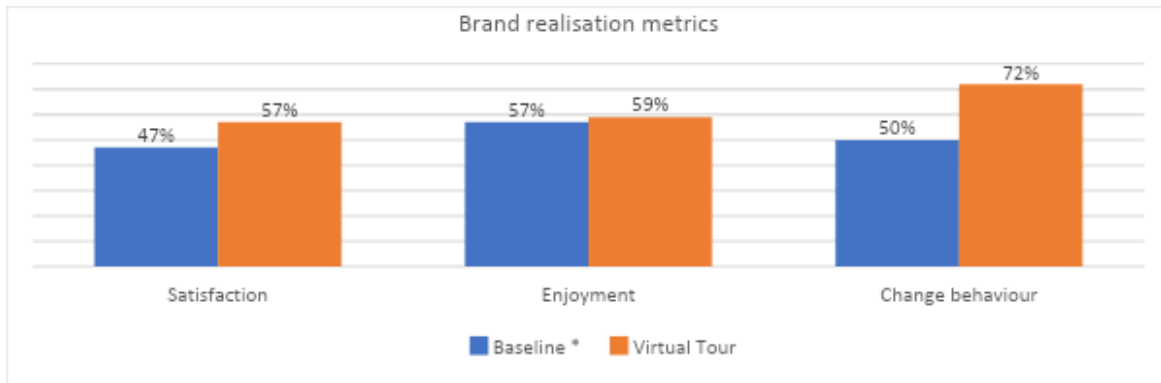
Nonetheless the VT experience helped enhance their knowledge - 77% agreed they felt more informed following the experience.

Likelihood to visit the Eden Project

The Virtual Tour of Eden is effective in raising awareness of the Eden Project, Cornwall and inspiring a visit.

Among those who had **never visited Eden** (42%), 80% said they would consider visiting Eden in the future as a result of the Virtual Tour experience. *"We don't live in Cornwall (London) and have never really been exposed to the project. A really good way of making us aware of what it is"*

Over half of all viewers had been to Eden before; 58% - 86% said they would visit again.



Satisfaction = % very satisfied (top box from 5-point scale likert satisfaction question) / Enjoyment = % agreed it was excellent (top box from 5-point scale) / Change behaviour = % Yes to questions did this help you think, feel, or inspire you to act differently
 *baseline data is taken from daytime onsite Eden visitors therefore should be used as a rough guide only

Evidence of results

Question	Metric	% viewers (96)
The experience provided a connection with nature	% top 3 box (7-point scale)	70%
Ease of navigation	% top 3 box (7-point scale)	73%
It was different from things I've experienced before	% strongly agree	35%
	% strongly agree + agree (top 2 box)	71%
It was a memorable experience	% strongly agree	33%
	% strongly agree + agree (top 2 box)	73%
It was absorbing, held my attention	% strongly agree	27%
	% strongly agree + agree (top 2 box)	79%
It made me think / feel / consider acting differently	% Yes	72%

Exemplar: Visitor Experience – Onsite AR - The Invisible Rainforest

Audience: Eden Project, Cornwall visitors

Eden visitors taking part in the trial were guided through the **Invisible Rainforest** experience within Eden’s Rainforest Biome by a Storyteller. Through never-before-seen augmented reality (AR) experiences provided visitors with visualisations of what exists beyond our human senses, bringing the invisible into view and explored the interconnectedness of the natural world to transform our understanding of the world – and how we interact with it.

Following their 1-hour guided Invisible Rainforest through Eden’s Rainforest Biome, visitors were then met by Eden’s *Head of Insight* who gathered feedback on their experience; all had agreed to do so prior to their Invisible Rainforest journey.

To understand how this immersive journey through the Rainforest compared to a typical visit, it was important to include visitors who journeyed through the Rainforest by themselves in the evaluation. We therefore had two different groups of people taking part in the evaluation:

Group 1: Trial Participants of the **Invisible Rainforest** (IR) journey

Group 2: Visitors who took a **Self-led** (SL) journey through the Rainforest biome. By this we mean, visitors who walked through the Rainforest Biome within their own groups, as they typically would do

Visitor feedback

Visitors were asked to provide feedback through a multi-choice questionnaire. This was completed by 58 participants (IR: **Invisible Rainforest** journey) 52 visitors (SL: **self-led** journey) across the trail period.

Data was captured via face-to-face interviews, also called in-person interviews, the oldest form of survey data collection. For this exemplar, we felt it was the best approach to minimise nonresponse and maximise the quality of the data collected.

The interview conversations were recorded (with participant approval), transcribed and included in the analysis as supporting evidence on feedback.

Description of results

Aim, outcome and potential impact

Aim	Outcome	Potential impact
Promote Eden’s mission; increase people’s connection to the living world and inspire action to create a better future	A new and stronger understanding of the interconnectedness of the natural world	Visitors think and feel differently about the vital connections between life and the environment
	IR participants had a much stronger connection to the Rainforest when compared to SL visitors	Stronger emphasis from IR participants to do ‘my little bit’ / ‘do more’ to help the environment – recycling, buying plants

For the majority of trail participants who took part in the **Invisible Rainforest** experience it resulted in strong feelings of visit satisfaction, an important measure when evaluating our visitors experience at Eden; nearly 9 in 10 visitors said they were **very satisfied** with their visit. Many **enjoyed** the experience; 6 in 10 thought it was excellent and a high 90% when you combine those who thought it was ‘excellent + very good’ (top 2 box).

Enjoyed experience

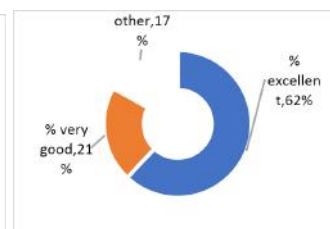
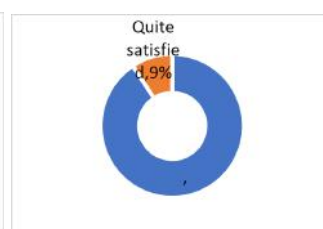
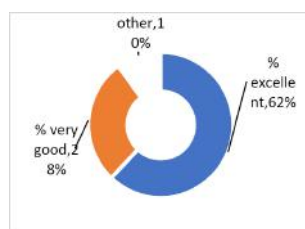
Visit satisfaction

Feeling of connection with the Rainforest

(Top 2 box, 88%)
box, 83%)

(Top 2 box, 97%)

(Top 2 box, 83%)

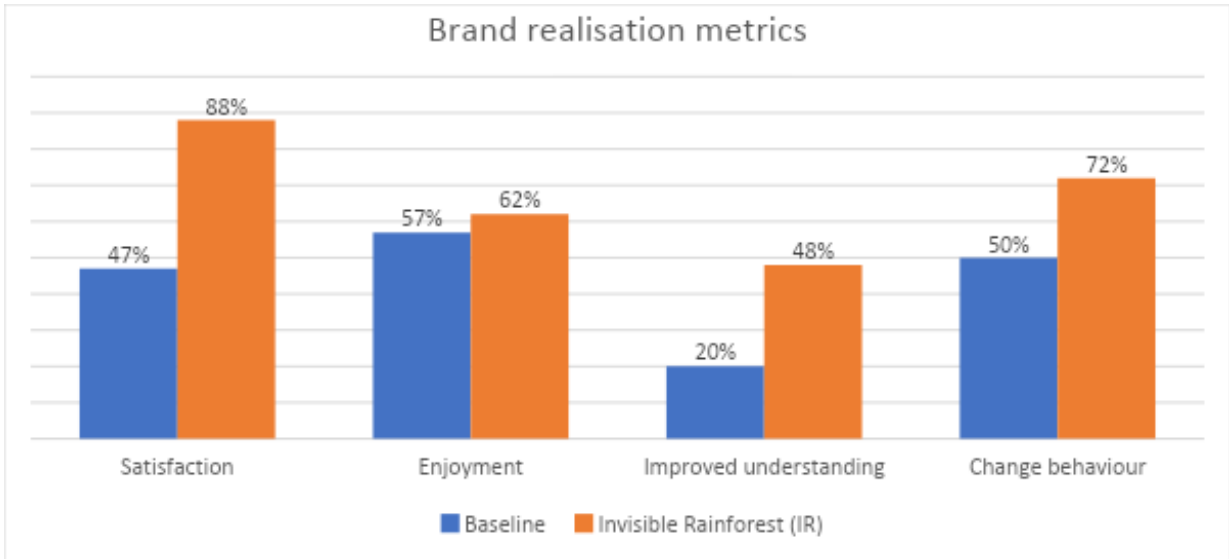


Answer choice: 5-point likert scale 5-point likert scale

5-point likert scale

Participants agreed that the experience was thought provoking (83%) & fascinating (79%). For 7 in 10 it was a memorable experience (71% strongly agreed). This in turn provided a strong feeling of connection with the rainforest; 83% thought it was excellent/very good (top 2 box).

When focusing in on brand realisation metrics, results recorded were above baseline. The immersive experience was especially impactful in providing participants with a better understanding of the interconnectedness of the natural world; 48% agreed that it ‘greatly improved their understanding’ which increased to 84% when combining the top 2 scores (Scale 1-5: 4+5).

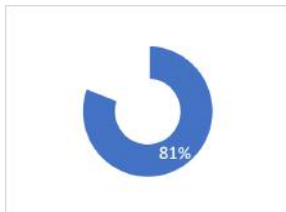


Satisfaction = % very satisfied (top box from 5 point scale likert satisfaction question) / Enjoyment = % thought it was excellent (top box from 5 point scale / NPS = net promoter score is not a percentage but / Improved understanding = % greatly improved my understanding (top box) taken from scale 1-5 where 1=has not improved my understanding and 5 = has greatly improved my understanding / Change behaviour = % Yes to questions did this help you think, feel, or inspire you to act differently
 Baseline: Eden Visitor Experience Research 4 weeks w/c 17th May 2021

Eden storytellers played a very important role in the delivery of this immersive experience. They received a 100% excellent rating. This is one of many comments which encapsulates visitor opinion
“They were brilliant, ‘first class’ really knows their stuff”

The Invisible Rainforest experience was effective in achieving part of Eden’s mission; to inspire visitors to **think, feel & act** differently

Inspired to ‘think’
(% yes)



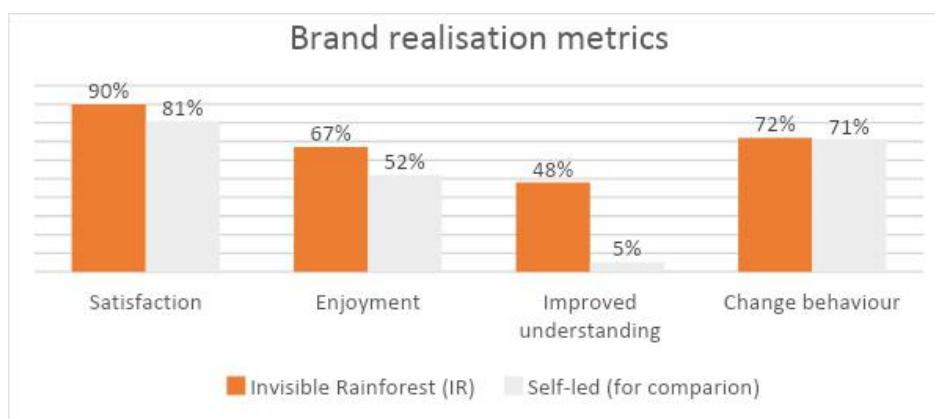
Inspired to ‘feel’
(% yes)



Inspired to ‘act’
(% yes)



When comparing both journey’s through the Rainforest; the Invisible Rainforest (IR) versus Self-led (SL) we can see visitors through the immersive experience gained a far better understanding of interconnectedness of the natural world than those on their own journey.



Evidence of results

Question	Metric	Results Trail visitors (58)	Results Self-led visitors (52)
Visit satisfaction	% very satisfied	88%	81%
The experience was great	% strongly agree	74%	71%
It was a memorable experience	% strongly agree	71%	76%
Knowledge on the interconnectedness of natural world	% expert knowledge	5%	5%
	% good/some knowledge	95%	85%
To what extent has Rainforest experience helped you understand the interconnectedness of the natural world	5=greatly improved (Top box)	48%	5%
	5+4 (Top 2 box)	84%	57%
To what extent has Rainforest experience helped you understand your own relationship with the natural world	5=greatly improved (Top box)	41%	0%
	5+4 (Top 2 box)	69%	62%
Feeling of connection with the Rainforest		62%	14%
It was absorbing, held my attention	% strongly agree	79%	48%
It was thought provoking	% strongly agree	83%	57%

Exemplar: Education

Audience: Teachers and pupils, 3x Cornish school/ 1x Cornish college

Three educational lessons were developed to suit a broad age range of students: Key stage 1, 2, 3 & 4. The format of delivery varied for each lesson:

Item	Key Stage 1 (Years 1 & 2)	Key Stage 2	Key Stage 3 & 4
Title of lesson	Invisible Rainforest Super Senses	Invisible Rainforest Signals and Senses	Invisible Worlds Rainforests - Climate Control
Length of lesson	60 minutes	60 minutes	80 minutes

Technology used	Living Lens 360 lookout camera 360 SEA camera	Living Lens 360 lookout camera 360 SEA camera 360 marketplace camera	Live broadcast via ZOOM from the Rainforest Biome using 2 x Samsung smart phones, DJI gimble, 2 x tripods with mounts, 2x Samsung earbuds, iPad x 2.
Curriculum links	Year 1 science KS1 Geography	Year 3-6 science	Photosynthesis, respiration, transpiration, working scientifically, climate change, carbon cycle, water cycle, interdependence, adaptations
Format	Led by class teacher using the screen in school. On demand	Led by Eden education officer from The Core building, streamed into the classroom via Zoom. Teacher is with the class and helps to facilitate the session	Led by Eden education officer

Timings and sample size

The education trials took place on 1, 2 3, 8 and 9 December 2021

	Number of pupils	Number of teachers use cases	Number of pupils use cases
Key stage 1: 3 classes	100	3	n/a
Key stage 2: 4 classes	75	4	n/a
Key stage 3 & 4: 23 classes	c. 530	6	59

Teacher and pupil feedback

Teachers were asked to provide feedback through a multi-choice questionnaire. This was completed by 13 teachers.

Data was captured via face-to-face interviews. The interview conversations were recorded (with teacher approval), transcribed and comments included in the analysis as supporting evidence on feedback

Pupils (key stage 3 & 4 only) were asked to provide feedback through a quantitative survey. Due to the volume of pupils involved in the live broadcast we wanted to engage as many as possible, survey data was captured using two approaches:

- 1) Paper surveys
- 2) Digital (pupils were given a QR code to access the surveys and unusually in their class, were invited by the teacher to use their mobile phone to scan the code to fill in the survey)

Description of results

Teachers involved in the trials were really satisfied with the lessons created and delivered by Eden. They gave top scores for the design, preparation, materials and pace of lessons.

All teachers were **very satisfied** with the lessons created by Eden. They thought the resources and technology surrounding the lessons were **outstanding**.

Teachers found the lessons **immersive** and **visual** which resulted in highly **engaged pupils**.

Importantly, it was felt students **met all the lesson goals**.

Teacher quotes

“resources exactly matched to what the children need to learn” Key Stage 1 teacher

“my pupils really loved it” Key Stage 2 teacher

“I’ve never had my pupils as quiet for so long” Key Stage 2 teacher

“Lesson activities pitched really well” Key Stage 3 & 4 teachers

The **live lesson** broadcasted from Eden’s Rainforest Biome was very well received by both teachers and pupils alike. 7 in 10 pupils enjoyed the lesson (Years 8, 9 & 10)

For teachers the most **valuable aspect of the live broadcast** were the interactive elements, being able to ask questions and have a discussion with Eden’s educator

Among pupils, the live and AR elements really helped them achieve lesson goals: it helped improve their awareness of the interconnectedness between themselves and the rainforest:

- 76% more aware of how rainforests affect the world’s climate
- 75% more aware of the threats to the rainforest
- 71% more aware of our impact on the rainforest

Pupil quotes

“It was very cool and I hope we get a lot more opportunities for learning like this” Pupil, Year 10

“I enjoyed how they made me think more about climate change more than I was” Pupil, Year 8

The AR content along with lesson activities really helped engaged and bring the lesson to life. To sum up the views of pupils, here are a few quotes:

“The augmented reality bits were really informative, it was as good to be able to ask questions. The oil nut tree was amazingly!!

“I really enjoyed answering the questions”

“I got a lot of information out of it”

“It was well explained”

When we asked the pupils what they most enjoyed about the lesson, learning about fungi was something that was mentioned by several. This is something that is not on the curriculum and interestingly was a topic that really piqued their interest. This quote sums their views up *“I liked the part when they showed us what was inside the tree and what the fungi give the tree and what the tree gives the fungi!”*

We asked the pupils to share at least 1 new thing they learnt

“The process where water travels up the tree and evaporated from the leaves is called transportation”

Eden’s education officer played a key role in the effective delivery of the live lessons:

“I liked the tour guy he was cool and explained a lot of thing”

“It was quite long, but Robbie (Eden Educator) was very enthusiastic and had a lot to tell us so it was worth it”

Evidence of results (note: small sample sizes): Teachers

Question	Metric	Results KS1&2 % (7 Teachers)	Results KS3&4 % (6 Teachers)
Satisfaction with lesson plan	% very satisfied	100%	100%
Ease of planning lesson	5 = very satisfied	100%	100%

More or less time consuming than other lessons?	5 = less time consuming	100%	
	4		80%
Satisfaction of lesson materials	% very satisfied	100%	100%
To what extent did your pupils enjoy the class?	% really enjoyed it	100%	8 in 10
Were your pupils engaged with the lesson?	% Yes	100%	8 in 10
Did the lesson add value?	% Yes	100%	100%
Did your students meet lesson goals?	% Yes	80%	80%

Evidence of results: Pupils

Question	Metric	Pupils % (59)
Lesson enjoyment	% yes	73%
How rainforests affect the world's climate	% more aware	76%
Threats to the rainforest	% more aware	75%
How climate change affects the rainforest	% more aware	75%
Our impact on the rainforest	% more aware	71%
The relationship between plants and animals in the rainforest	% more aware	66%
The cycles of water and carbon	% more aware	66%
Our connection to the rainforest	% more aware	63%

Exemplar: Health & Wellbeing

Audience: Care home residents

Three Care Homes in Cornwall along with one in Liverpool trailed three experiences designed to support the health and wellbeing of care home residents through positive engagement with a virtual experience of The Eden Project.

Experience	Care home
iPads with headphones	Cornwall Care Home 1 + Liverpool
'Room with a View' – projector screen with speakers	Cornwall Care Home 2 + Liverpool
VR (Virtual reality) headsets	Cornwall Care Home 3 + Liverpool

Staff and resident feedback

Plymouth University led the evaluation for Cornwall Care Homes. They applied both a quantitative and qualitative approach to capture feedback from participants.

For the collaboration with Liverpool, Eden led the evaluation, also applying a quantitative and qualitative approach albeit the quantitative survey differed. Care Home staff talked through the survey with each resident and shared their observations on resident usage of the experiences through a messaging app direct to the Eden team.

Note: Due to the ongoing pandemic Plymouth University have been unable to access the care homes to obtain clean data as final evaluation of the 3x Cornwall based care homes.

Description of results

Care Home, Liverpool collaboration

For the Liverpool collaboration, we applied the WHO (Five) Well-Being Index approach to evaluate participants response to the experience. This paper survey was asked to 6 participating residents, (many others took part but were not evaluated). The surveys were administered by the Care Home team.

We are delighted to report that the collective resident WHO wellbeing index went from 52 to 61, an uplift of 17%:

Collectively among the residents, the WHO index was 52 on the week the experiences were installed in the home (w/c 1st February) rising to 61 nearly two months later. This was a 17% increase in the participants well-being. Anything over 10% is classified as significant.

Staff observations

Following their participation in the experiences, residents had a greater sense of connection with the outside world and other people, learning new things and feeling more confident using technology.

Staff *"They are getting used to the iPads and a couple of them said they thought it would be harder to use"*

Staff *"After seeing the waterfall in the Rainforest Biome, she would like to learn more about the different waterfalls around the world so that's something we are going to look at"*

A few things the residents said

Resident 1: *"She said what a lovely peaceful place Eden is and how nice it is to see the different images of the rainforest"*

Resident 2: *"She thought it was a relaxing experience, felt calm"*

Resident 3: *"He absolutely loved it and was so happy"*

Care Home 1, Cornwall

iPads with headphones experience

29 residents, with different levels of dementia. Only those with capacity gave feedback. The home mostly caters for residential care, but some residents also receive nursing care.

Residents

Resident feedback suggested that they enjoyed the experience of using the tablet, in particular looking at the plants and flowers:

"its all very pretty, that's all I can say" (Resident 1)

"Oh, its absolutely beautiful, and I love the plants" (Resident 2)

One resident was intrigued at how they had managed to get the Eden Project onto one small screen:

"I think its wonderful to look at, I just don't understand how they did it, how did they get it like this?" (Resident 1)

"I don't know how to explain it, to [family members] when they come up, but I just touch it and see all these lovely pictures" (Resident 1)

Seeing the experience on the screen also got residents talking about their real-life visits to the Eden Project:

"Oh Yes, I've been many many years ago, when it first opened, oh and it was lovely" (Resident 1)

"Oh yes, its one of my favourite places to go...we used to look at all the different plants and everything" (Resident 2)

One resident expressed how using the tablet made it feel like they were at the Eden project and didn't necessarily have to visit in real life:

"Well I don't think I'd go there especially for that, when I can see it here" (Resident 1)

Researcher: *"So does this feel a little bit like you're there [at the Eden project]?"*

"Well yes dear, it does" (Resident 1)

Staff

Feedback from staff focused on four main themes: 'experiences, 'benefits' 'challenges' and 'suggestions for improvement'.

Experiences

Staff expressed that the time using the table ranged between 2 and 30 minutes and this was dependant on residents' capacity to take in the experience on any given day. The home has also had one experience where a family member became involved with the use of the tablet, with the resident teaching the family member about how to use the experience:

"I was up there with her and she was doing it in her room, and her daughter came to visit and she took over... so I left them it and they were having a go with it. She was teaching her daughter" (Staff member 1)

"One gentleman that I did it with...he didn't want me to take it away, I was with him for at least 20-minutes, half an hour...he was like 'I'm not giving it back'" (Staff member 3)

"Some of them will shut if off really quickly...literally two minutes" (Staff member 2)

Benefits

iPads were portable which was useful for offering the experience to residents in their rooms, but the small screen also required dexterity and good eyesight which some residents didn't have.

"Its easy to carry around, easy to take into any room...its not heavy" (Staff member 1)

Staff also felt that the tablet helped to facilitate conversation between themselves and the residents, but also between residents

"Because you see the flowers, you're talking about the flowers [with the residents]" (Staff member 1)

"I know a couple of them [residents] will say 'oh I'm doing that, that tablet thing' and then one might say 'oh I've been there', so between themselves as well" (Staff member 1)

Challenges

High levels of support needed to facilitate iPad use with residents due to resident skill, but also it being a one-to-one activity rather than a group activity.

"It was really hard to start with...very hard. They [the residents] just didn't get it...it wasn't so much what they were seeing it was the using the iPad" (Staff member 1)

Low staffing levels due to COVID impacted the first month of use, where it was difficult to focus on iPad use, due to the high levels of engagement needed from staff:

"We were doing everything, in the kitchen, doing activities...so it wasn't really focused on the iPads...but the last month and a half, obviously the main priority of activities has been the iPads" (Staff member 2)

"Its hard because the iPads do tend to be one to one...and when you've got 28 others looking at you going 'well what are we going to do?'...it really does take you off the floor" (Staff member 1)

When asked if residents could use the tablets autonomously there was a resounding agreement among the staff that their use would always need to be supported by staff:

"No, not a chance, it would never happen...they wouldn't be able to navigate it" (Staff member 1)
The use of the headphones was also limited due to the support needed from staff:

"We don't really use them [the headphones]" (Staff member 1)

"A lot of them need constant reassurance as well, so obviously we're like taking them off, putting them back on, taking them off, putting them back on to explain it, and it was getting a bit of a fuff"
(Staff member 2)

Suggestions for improvement

Based on these limitations staff spontaneously suggested ways of improving the experience including using a bigger screen to make the experience for multiple users and to include a more immersive perspective:

"You know what would be good, like google street view, so you could click and like have it as if you were walking round, I think that would be really good" (Staff member 1)

"We have a magic table here...I think if that was projected onto the magic table that would be amazing...then it would be a group involvement" (Staff member 2)

"Resident is inspired to learn more about the different waterfalls around the world"

"Resident said he absolutely loved it and was so happy"

"What a lovely peaceful place Eden is and how nice it is to see the different images of the rainforest"

"Relaxing experience, feel calm"

"Absolutely love it and feel so happy"

Exemplar: Arts & Culture

Rainforest Reconnect: a live-streamed musical wellness event

Audience: online viewers

The content for the live event from the Rainforest Biome was created by Alice Boyd who created a 5 track EP; taking data from the plants in the Rainforest Biome, created melodies which were sung by a choir for the event. Visuals to enhance the experience were seen through yoga and dance.

Viewers feedback

Viewers were asked to provide feedback through a multi-choice questionnaire accessed online immediately post the live streamed event. This was completed by 38 viewers.

Description of results

The live-streamed wellness event was well received by viewers, enjoyed by all. In their own words:

"It was something really different, immersive, I really enjoyed it"

"Would love to see more of this in the future. Love the concept!"

“The concept for this project is breath-taking, and executed beautifully”

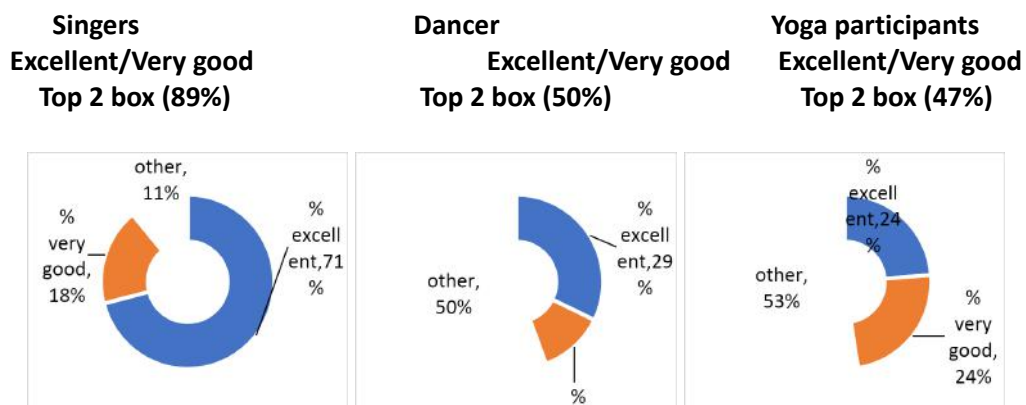
Nearly 8 in 10 viewers were satisfied with the live streamed event (% very satisfied + satisfied). While nearly 7 in 10 thought (66%) thought it was excellent.

Viewers thought it was an interesting idea (82%) which was well designed and executed (61%).

Elements designed to visualise the music were all very well received especially the singers

“The composition of the pieces (music and lyrics) was wonderful”

“The singers were amazing”



Answer choice: 5-point likert scale: Excellent-Poor

While the Narrator was positively received, 74% said he was excellent/very good, for a small few they would have liked better lighting to enable them to see him more clearly and would also have liked the capability to zoom in closer so as to allow them to further engage with the overall experience: *“I couldn't see the narrator close enough, which meant I didn't make a good connection to him and what he was saying”*.

The most common words used to describe the live event was that it was relaxing, soothing and beautiful



Q. What 3 words would you use to describe the event?

Likelihood to visit the Eden Project

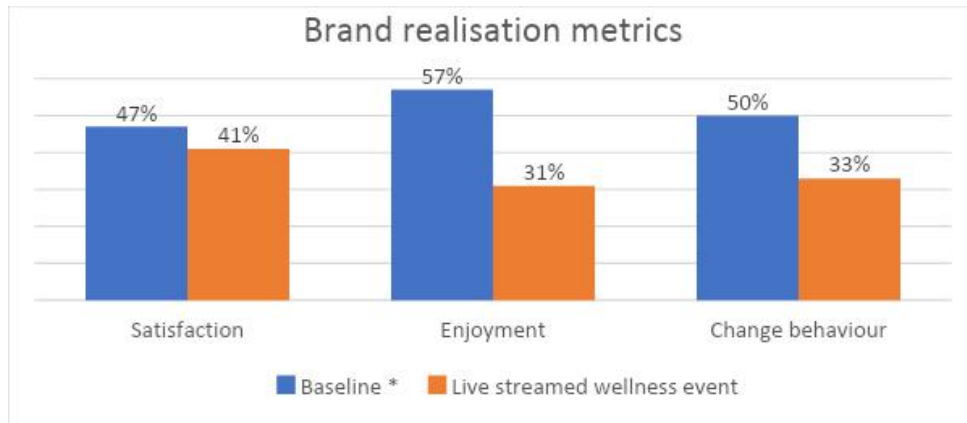
Most viewers had been to Eden before; 71%. The majority agreed as a result of this event, they are likely to visit Eden again. Among those who **had never visited Eden** (29%), **all said** they would consider visiting Eden in the future.

Importance of device used

We asked viewers which device did they use to access the live event, over half (55%) accessed it on their laptops. Interestingly, those who viewed it on their laptops enjoyed it better than those watching on either smartphone or iPad

Evidence of results

Question	Metric	% viewers (38)
Experience rating	% excellent	32%
Experience rating	% excellent + very good (top 2 box)	66%
Satisfaction	% very satisfied (top box)	42%
Satisfaction	% very + quite satisfied (top 2 box)	76%
Feeling of connection with nature	7 = very strongly (top box)	16%
Feeling of connection with nature	6+7 (top 2 box)	34%
It was an interesting idea	% strongly agree (top 3 box, 10p scale)	82%
It was well designed and executed	% strongly agree (top 3 box, 10p scale)	61%
It was a memorable experience	% strongly agree (top 3 box, 10p scale)	61%
It was different from things I have experienced before	% strongly agree (top 3 box, 10p scale)	63%
It was thought-provoking	% strongly agree (top 3 box, 10p scale)	58%
It has something to say about the world we live in	% strongly agree (top 3 box, 10p scale)	55%
The experience transported me elsewhere	% strongly agree (top 3 box, 10p scale)	55%
It was absorbing, held, my attention	% strongly agree (top 3 box, 10p scale)	47%
It felt amateur	% strongly agree (top 3 box, 10p scale)	3%
It was confusing, I didn't know what was going on	% strongly agree (top 3 box, 10p scale)	3%



Satisfaction = % very satisfied (top box from 5-point scale likert satisfaction question) / Enjoyment = % agreed it was excellent (top box from 5-point scale / Change behaviour = % Yes to questions did this help you think, feel, or inspire you to act differently
 *baseline data is taken from daytime onsite Eden visitors therefore should be used as a rough guide only

5. IMPACT OF RESULTS

A FOUNDATION FOR THE FUTURE

The overarching impact of the testbed has been that Eden Project, Cornwall now has the foundations of a network and infrastructure that will lend itself to new and exciting opportunities across the sectors related to all the exemplars and allows us the opportunity to increase the hardware to the required network capabilities in the future.

Thanks to the deployment of the use cases, the consortium has obtained a wealth of information and feedback as to how these technologies can be utilized by similar tourist destinations nationally and internationally.

USE OF TECHNOLOGIES

After 18-months of R&D and content deployment, the consortium has come to the conclusion that the use of technologies to share the Eden Message has been invaluable and, in response to the Testbed and Trials programme, will result in a more digital approach to this in the future, both onsite and online.

As per the BR results across the different use cases the digital experiences curated have enabled us to expand our message to a worldwide audience, while our data suggests that the visitor enjoyment onsite has only slightly increased, the digital experiences onsite and online have either introduced or strongly increased our audiences understanding of the interconnectedness of the natural world and meant participants have a strong connection to nature.

While our results have been confined to our sample groups, we still feel that the feedback will stand up to a public roll out of experiences.

Based on sample group feedback The Eden Project has plans to deploy an enhanced version of the Virtual Tour to the public as part of its existing website offering. We believe this will not only appeal to those that intend to visit the site by giving a high-quality insight to the venue, but will also act as a digital visit for those that are unable to attend the Cornwall site.

A series of video edits have been created to document the work and outcomes on the project that will be used to showcase the new capabilities of Eden Project to new partners and audiences.

We intend to develop and deploy the experiences delivered as part of the Health & Wellbeing and Educational as Eden Products in the future and already have interest from Liverpool based care homes based on their participation in the use case trial.

The Art & Culture exemplar has allowed us to step into the world of virtual events, meaning Eden now has the knowledge and technology to deliver its own world class events, but also to show potential outside partners/promoters what we are able to deliver for them to come in and utilize the network as part of a financial contract with us.

One of the main outcomes is that we have solidified the need for human connection when sharing our message. The use of storytellers for the onsite AR journey, the inclusion of Eden Project team members appearing in welcome videos on the virtual tour, and the fact we were able to live stream our educational team increased that connection to the outside and natural worlds and we feel enhanced the digital offering of the use cases.

All of the above will also be taken into account when developing the new Eden Project sites around the world and has effected a change in our thinking towards themes, experiences and exhibits.

ONSITE EXPERIENCES

The results achieved with the onsite experience have been very interesting and beneficial to the future plans of the Eden biome experience and future site development.

As to create a baseline, sample groups were evaluated on a self-led tour that included no technological enhancement. Feedback allowed us to understand the already high quality offering that visitors were able to experience.

While the introduction of technology increased visitor satisfaction from 81% to almost 90% it is the fact that the feeling of connection to the rainforest increased from 14% to 62% which is incredible.

It has given the internal team evidence that guided VIP and the introduction of more digital exhibits and experiences is something that Eden Project should and will utilise in the future.

THE “EDEN UNIVERSE”

The development of the Eden Universe is one of the biggest outputs of the whole project.

Thanks to the collaboration with 3DEEP media and Plymouth University the project has been able to deliver a high-quality user experience that would be available for deployment as a customer facing platform to be used by Eden Project in the very near future.

Its ability to connect [people from around the globe to the site and give live streamed views of the site and its nature has been invaluable.

Based on the detailed feedback on the UX the team at Eden Project are now working with the developer to enhance the experience so that it is suitable for final deployment on the Eden Project main website.

By deploying this we will be able to share our stories and mission to persons around the globe that would not normally be able to experience them, as well as use elements for our educational and wellbeing offerings.

EDUCATIONAL DELIVERY

With the success of the Educational use case trial the result is that Eden has a digital offering that can readily be rolled out to existing and new partners/schools. The learnings and equipment available now will mean Eden will be able to share its educational offering in a new and more engaging way to existing.

But we would now be able to share these lessons across the globe and to multiple schools at once increasing our capabilities to interact exponentially.

HEALTH & WELLBEING

After deployment of the Health & Wellbeing experiences to care homes in both Cornwall and Liverpool the result of our evaluation is that the content and delivery mechanisms have merit for redistribution and opportunity for enhancement.

For instance, this presents the possibility of developing a sensory room that incorporates the virtual aspect of the tour in a more immersive experience utilising projectors. This could be deployed at care homes but also for other visitor demographics that would not be able to visit Eden or leave there surrounding such as schools, deprived areas of country or even prisons.

One of the impacts of the results however is that we understand now that the experiences need to be deployed in locations where the activity coordinator has the time and vested interest in utilising the experiences with residents.

We found in the Cornwall care homes, due to their responsibilities and workload, that the activity coordinators were unable to interact with the residents as much as the Liverpool ones. This meant that the findings were less positive from one care home to another. We do however feel this issue will be negated as an institution that decides to financially pay for the experiences to be deployed to their residents would have a vested interest in ensuring the activity coordinators use the equipment and experiences to the best of its abilities.

IoT

The IoT development throughout the project could be one of the most exciting elements. While the consortium focused heavily on the use cases and customer experience a smaller team worked together to introduce a small number of sensors to and a data lake that will be the foundation of a journey that could transform the way Eden Project Cornwall and the wider sites operate in the future while, similarly to our digital offerings, has allowed us to start thinking differently.

The introduction of IoT thinking will contribute to customer experience, operations and our target to be climate positive.

When considering customer experience data collection will be a large part of Eden's methods from understanding our customers enabling the team to better equip the sites for guest needs, this would be in the form of experience evaluation and journey mapping just to start.

Operationally the IoT will enable us to understand our site and its visitors which will in turn increase efficiency thanks to our understanding of customers and the venue infrastructures while also lowering overheads as a result of the aforementioned and our monitoring of metres etc.

Lastly our mission to be climate positive can be monitored throughout the site, its building, its infrastructure and its visitors – as well as linking with Eden’s Geothermal efforts. This will be illustrated to the general public to help them to make decisions and change their actions towards helping the planetary emergency.

DOCUMENTATION

The delivery of the use case trials also allowed the consortium to curate showcase videos that highlighted the work carried out and the high-quality products that were delivered.

These videos will be utilised in final reporting to DCMS and for internal evaluation purposes but also will be available for use to showcase the content, site and skills of Eden and its partners.

While they can be used as advertising tools in a more general sense on social media and other digital media, but also to be shared with would be partners that would show interest in utilising the services of the consortium or the venue/network now located at the Eden Project site.

6. KEY LEARNINGS

SUPPLY CHAIN

With the removal of Huawei from the supply chain and ZTE considered high risk, the UK RAN market became heavily reliant on Nokia and Ericsson. Unfortunately, these suppliers were reluctant to enter into agreements with small, private network providers. This put a strain on the remaining smaller UK suppliers who did not have the high levels of R&D investment required to compete in the RAN equipment market. Unfortunately, the supplier chosen by aql was not able to deliver fully functioning 100MHz RAN equipment to any of the 5G Create projects prior to project completion.

During the course of the project, it became evident that a significant amount of the technology was still in the development and testing phases despite being available for purchase. An attempt was made to change supplier but, due to the complexities of the commercial agreements involved, we were not able to get an order in place prior to project close. With an extension, we may have been able to deliver the full scope of the project.

NETWORK RESTRICTIONS

Ultimately, the final delivered technical experiences across the exemplars and Eden Universe project are not exactly as those defined at the start of the project. There are a number of core failures and shortcomings that changed the final delivery quality and impacted the exemplar success in a number of ways.

Generally, the impact on experiences can be broken down to:

- Supply chain issues resulting in an inability to deliver complete 5G activation across the Eden site
- A mismatch in the actual network throughput and presumed network performance
- Technical complexity in the narrative journey tools onsite leading to repeat issues in experience deployment

Due to a number of externally impacting and uncontrollable factors, as outlined in our key learnings portion of this report, the overall implementation of a bespoke 5G network within the Eden Project had not happened fully or completely at the time of exemplar execution. This meant the consortium were unable to facilitate and install suitable infrastructure onsite in time to satisfy the needs of the project. While mitigations and alternatives were implemented, in the form of a specific Wi-Fi 6-high throughput network, it was not up to the same quality or expectations of the original 5G scope.

This implemented Wi-Fi network, while robust and vast within the scope of conventional network infrastructure, did not allow the same control, management or bandwidth regulation as a bespoke 5G network would allow. This ultimately meant that the onsite infrastructure could not handle the data rates agreed or set out at conception required for the render streaming AR experience and high-resolution 360° camera management. In mitigation attempts Eden Project installed a new 1-gig fibre backbone pipeline into the site, allowing faster data in and out of the complex, but the onsite connected infrastructure would never reach the levels needed for more complete and complex integration of the onsite AR experience, one of the most technically progressive and “at the edge” parts of the project's appeal. The actual impact to the project resulted in the number of users and devices active at one time going from a targeted 12 to a rescope six leading to only two in the final deployment as the network could not be calibrated in a suitable way to deliver, and the overall quality of the direct streamed content to have obvious latency in the final product in remote user camera predictions.

A focus on the mitigation and management of the network onsite led to a drop in the overall quality assessment (QA) and testing time allocated to the technically complex parts of the project. Specifically, the onsite visitor experience with streamed content to iPads. Developed as three independent spaces the lookout camera, living lens and weather maker all worked as isolated experiences in the offsite staging area, but there was an underestimation in the time required to integrate all of them into a cohesive narrative journey app to support the storytelling guide. Vast amounts of time and resources were utilised reducing, redeveloping and altering the existing systems to better suit the onsite network capacity, and as a result of this causing project delays the app development and integration was not fully tested or QA'd prior to handover. Leading to a less than perfect experience in the hands of the invigilating group.

The lack of bandwidth available to the project partners across the network also led to restrictions to the live streaming of the Meta Cameras. While we were able to relay data from the static cameras through ethernet cabling this was not the case with the vertical, horizontal and roaming cameras.

For the vertical/horizontal cameras Meta were able to deliver a temporary wireless bridge to send its signal to a strategically placed wired access point rather than utilising a fit for use wireless bridge that would interact with originally spec'd 5G radios.

For the roaming cameras the effect of an underperforming 5G network has meant that they can only be utilised in strategic locations that are within close proximity to wired access points rather – this has restricted their use greatly for live streaming as it was hoped we would be able to place them anywhere on site.

There were a number of issues and unresolved consequences of the onsite networking infrastructure not reaching the ambitions of the project in a number of ways, which we had hoped to answer through a project extension. Ultimately a large portion of the project's final deployment was spent managing expectations with the experience, rather than QA testing, ensuring stability, robustness and scalability which are normally key pillars of any public-facing project.

The “Beta” or R&D nature of the project allowed a lot of cuts that otherwise are not sustainable or appropriate in commercial projects but ultimately allowed us to deliver the project at a suitable and desirable level.

Due to Plan B delivery of network to support the use cases, the 5G network delivery has not significantly improved from the early testing. Whilst not fully realised in the testing at Eden, aql’s indicative tests of a working 50mhz (and then lab samples of 100mhz) networks show performance was capable of supporting the networking demands of this project however the real-life testing on site was far from it due to equipment deficiencies.

VIABILITY OF A 100MHz NETWORK

Due to Plan B delivery of network to support the use cases, the 5G network delivery has not significantly improved from the early testing.

While the project has deployed its use cases within the restricted Plan B network and aql have carried out indicative tests on the 50MHz site network and lab samples on 100MHz, the project ultimately has not been able to visualise the full capabilities of a 100MHz RAN network in the unique environment provided by the Eden Project site.

Whilst not fully realised in the testing at Eden, aql’s indicative tests of a working 50mhz (and then lab samples of 100mhz) networks show performance would possibly be capable of supporting the networking demands of this project however the real-life testing on site was far from it due to equipment deficiencies.

Due to this, we do not currently know how well the network would connect the entire Eden site and whether it can penetrate the Biomes, the foliage and other restrictive elements.

This is something that aql and Eden Project are intending to work on together within the next 12 months.

SECURITY

We utilised secure by design methodologies in this project from a networking infrastructure perspective and saw no issues presenting a secure network for the use cases set out. When dealing with mobile network and sim provisioning; practices were put in place for sim cards created for the project use to ensure secrets were not shared with outside parties / limited view by enforcing a least privilege methodology. Future projects would potentially include more robust OSS/BSS.

LICENCING

aql encountered many hurdles when applying for Ofcom licences and were often met with inflexibility. It also became apparent that the main network providers have a strong hold on the available spectrum. Given the technological developments, the increasing reliance of rural communities on private networks and the Government support for supply change expansion, it would be an ideal time for Ofcom to be willing to discuss the issues many private network suppliers are encountering and release more of the spectrum to those smaller, private network providers.

ENVIRONMENTAL IMPACTS

A large quantity of the technology deployed was within the Rainforest Biome situated at the Eden Project Cornwall site, including the camera units.

These Meta Cameras are not completely weatherproof, they are rugged and robust but they were not originally designed to withstand the kind of environment that Eden represents. The biggest risk to the cameras is actually water ingress. This is somewhat mitigated by the careful sealing of the cameras with a form of silicone when they are assembled. This silicone is carefully piped over all the joints and seams of the camera. We also then seal any unused ports, such as HDMI or camera card ports.

We have found though that just sealing the camera with silicone is not enough, the high levels of humidity in the biome means that water can easily collect inside the cameras, especially during periods of temperature change (drop). The way we have found to keep the cameras consistently dry and running reliably is simply to keep them powered on. As we are always streaming this is OK, but when we lose power for an extended period we have a problem.

As a result of this susceptibility, we have setup alerts on our servers to let us know when we lose contact with a camera and in turn alert the Eden team so they can investigate the issue. Once power is restored the cameras automatically boot back up and resume streaming.

Not only have we had to deal with water ingress but as we have deployed technology in a living rainforest, we have had to deal with all manner of small insects including ants and cockroaches. While we have ensured we utilise IP rated equipment it has meant that we now know that certain units will not have the same life cycle as when they would be utilised in an alternative setting.

LIFE CYCLE ANALYSIS

Throughout the duration of the project members of the delivery team from aql and Eden Project chaired and contributed to a Climate and Environment working group.

As a result of this work a relationship was created with a consultancy that intended to carry out a life cycle analysis of the project. Unfortunately, due to the issues surrounding supply chain of 5G networks we were unable to carry out this assessment which would have given us valuable knowledge on the environmental impacts of 5G networks.

SOCIAL ACCEPTANCE

One of the most interesting learnings from the project focused on the implementation of a 5G network into a public space, in a very public manner, during a time in which a lot of ridicule was focused on the impact of novel wireless technologies on the general health & wellbeing of the population.

While there was no direct action towards the Eden Project of the Eden Universe project, a small number of members of the public did raise concern and general alert to the limited access that adding 5G in such close proximity to a natural space adds. One such member of the public suffering from a medical condition, known as electro hypersensitivity syndrome, meant they could no longer comfortably visit Eden Project while the 5G mast was present.

As 5G becomes a more and more synonymous term for wireless connection and network throughput, awareness, and policy around what is and isn't '5G' as a networking system at an end-user or laymen term logic needs to be developed. While there are strict operating limitations and definitions, what an end-user can expect in terms of 5G application and integration was something that the project team had to learn first hand as principle sometimes does not translate into practice.

This project dealt with the specific tasks of developing new technology to enable exemplars for public consumption in otherwise established verticals of tourism and visitor attractions. Consumer guidelines and methods for engaging with customers and the public on the integration of developing technologies into otherwise 'conventional' industries need better public image perception and guidance to ensure public buying at all levels of experience.

We had originally planned to carry out further research and comms in these areas, however due to the restrictions of the projects 5G deployment we were unable to do so.

7. CONCLUSION

While the Eden Universe did not meet its original intended goals of deploying a 360° 5G non-standalone (NSA) shared spectrum network, the works carried out for the past 18-months have far from been in vain.

The Eden Project Cornwall has been able to experiment, learn and grow with the project to ensure that its future offerings and execution not only utilise the network, devices and materials that have been deployed, but it has also encouraged us to think differently about how we share our message in the future.

The use case trials have been able to showcase the talents of the teams within Eden and the consortium partners creating video and content-based evidence for future business partnerships and potential applications for future related testbeds.

Working relationships have been created and streams of work, that would not have been possible to help highlight the planetary emergency, would not have transpired if not for the opportunity presented by the 5G Create Testbed and Trials programme.

The testbed comprehensively satisfied the question set out to be answered at the start of the testbed, 5G technologies are a necessary requirement to enhance Eden's visitor journey onsite as well as online, and this digital offering does very much increase our audience reach nationally and internationally.

It also aids to enhance Eden's mission of creating a movement that builds relationships between people and the natural world which was evident in the evaluation of the onsite tour where we found that our sample groups feeling of connection to the rainforest increased from 14% to 62% which was incredible.

It is now the responsibility of the consortium partners to take these key learnings forward to help with the research, development and deployment of 5G into the future for Eden Cornwall and its other sites around the world.