9. Venue Design - The Gaia

9.0 Venue Design - The Gaia

9.1 Overview

The Gaia Building

Sitting at the heart of a spectacular living campus The Gaia building will capture the hearts and minds of all those that enter. Students, lecturers, school children, local residents or national and international visitors, The Gaia will challenge, excite and educate all who visit.

It will be a venue which will inspire the future green leaders of our time, a campus like no other, leading the regeneration of Karvina from black to green.

Five key design drivers were established in response to the brief. These are summarised on the next page and these were used as principles throughout the feasibility design process.

9.2 Design Drivers

Symbol of Transition

A venue which represents the journey of Karvina from black to green

Iconic

An unforgettable campus which will become a symbol for the future

Nature Inspired

A destination which is inspired by nature and responds to nature

A Living Campus

Responding to its context and in harmony with its setting

Welcoming and Inclusive

A hub for students, the local community and visitors alike

Options Development

9.3 Options Development

Three options were explored in response to the site:

1. An Extension of the Landscape

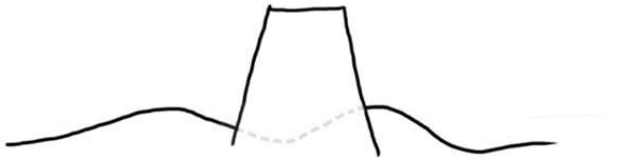
A form inspired by the undulating landscape, a building which blends into green.

Typology of the site

2. Growing from the Landscape

A symbol of growth, a new vertical form emerging from the landscape, to replace the historic mine shafts.

Darkov mine



3. Carving through the Landscape

Exposing the layers of history, carving through the site expressing the strata of the land.

Stonavka river

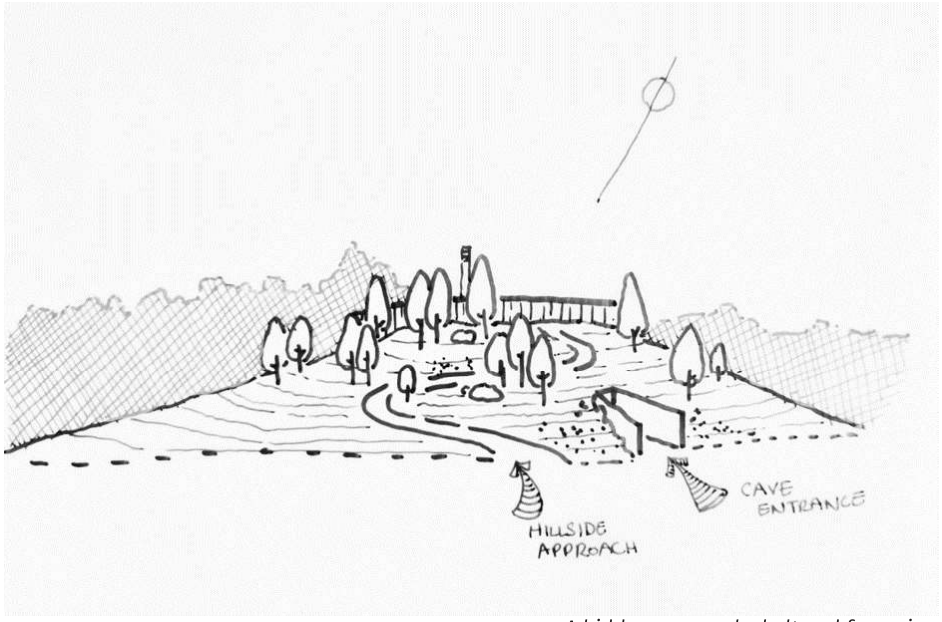
9.3.1 Option 1 - An Extension of the Landscape

- A hidden building
- Creating fantastic views out across the landscape
- Observing nature rather than being immersed within it
- Passive solar gains to the south
- Sheltered north buried into the land

Early sketches

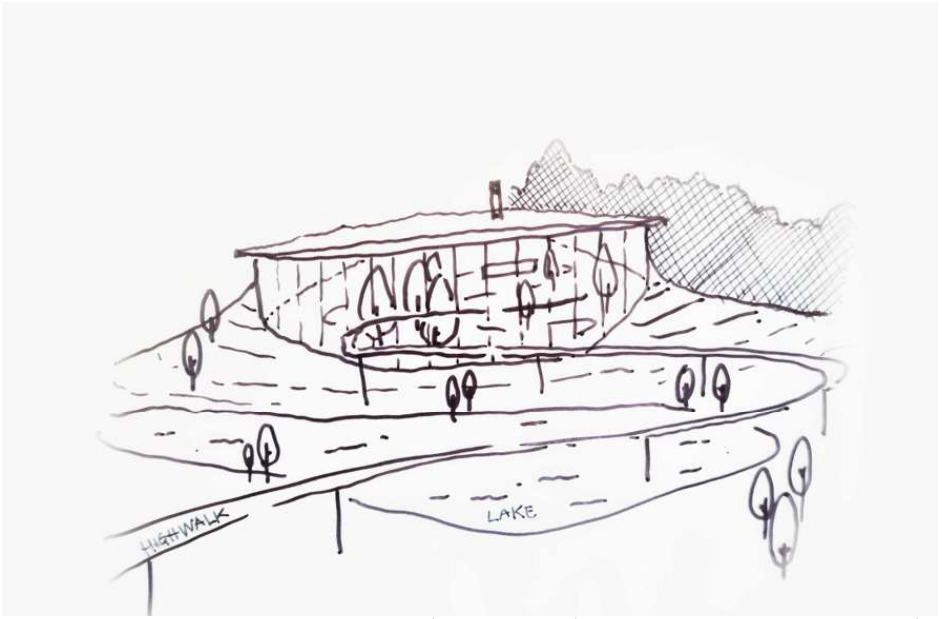
9.3.1 Option 1 - An Extension of the Landscape

North entrance view



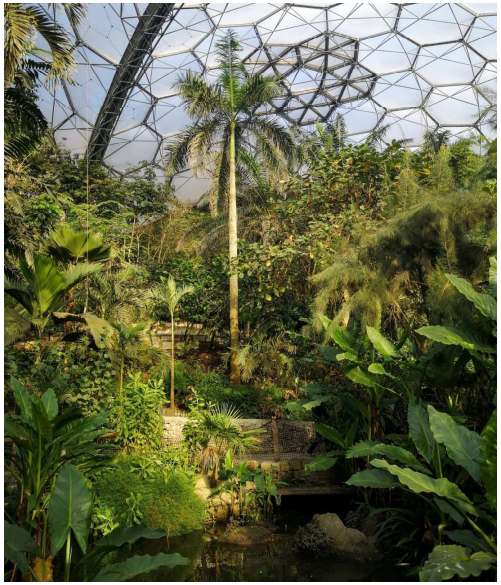
A hidden approach sheltered from view

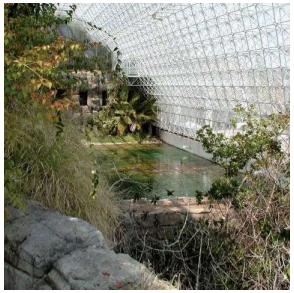
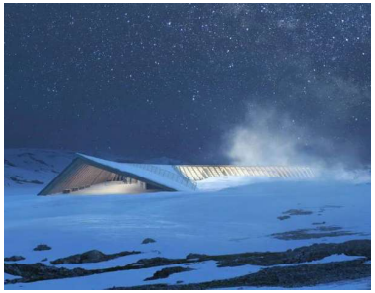
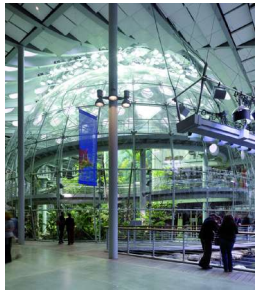
South facade view



South elevation embedded into the natural typography of the site

9.3.1 Option 1 - An Extension of the Landscape

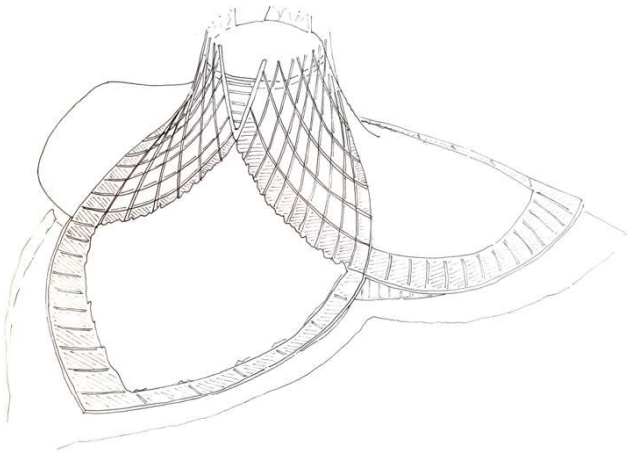


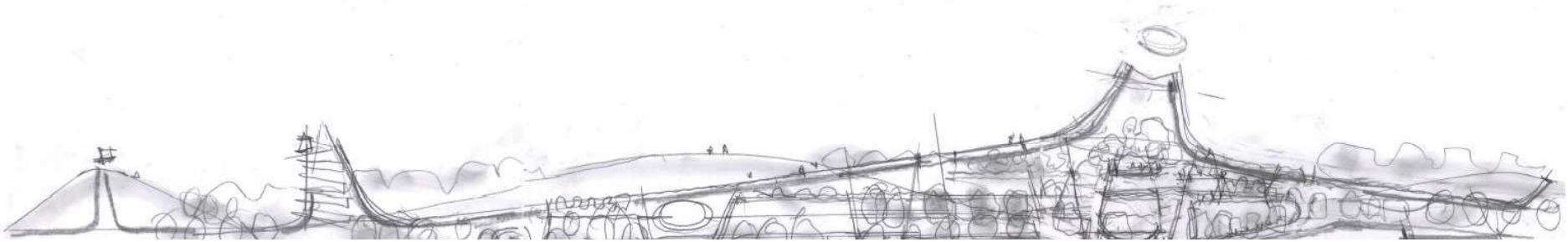







9.3.2 Option 2 - Growing out of the Landscape

- A green eruption growing out of the old coal mining landscape
- A symbol of a new beginning
- A simple efficient form inspired by nature
- Inhabitants are immersed in nature and connected at all levels and in all directions

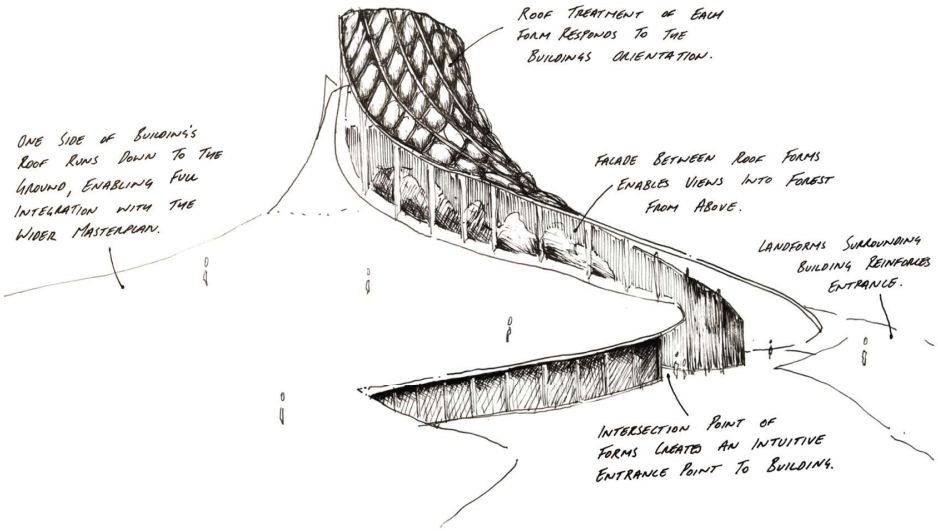




Early sketches

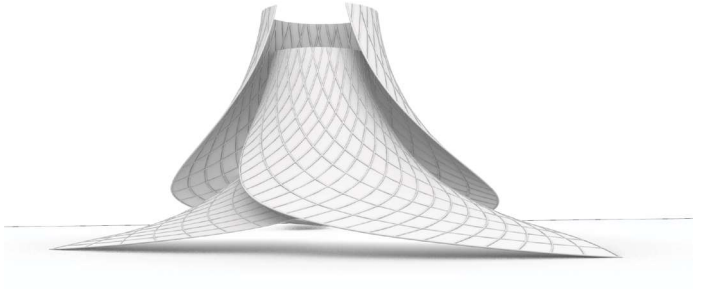
9.3.2 Option 2 - Growing out of the Landscape

North entrance view

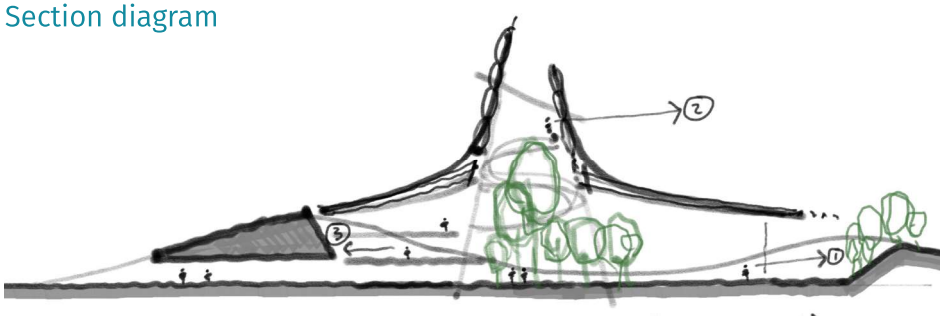


A building which emerges from the landscape, exciting and intriguing

3D form

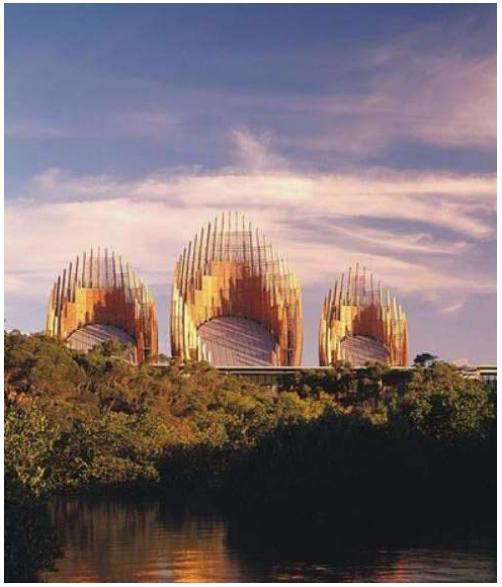


Section diagram



Responding to the typology of the site and growing from it

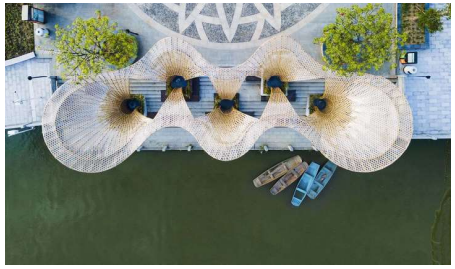
9.3.2 Option 2 - Growing out of the Landscape





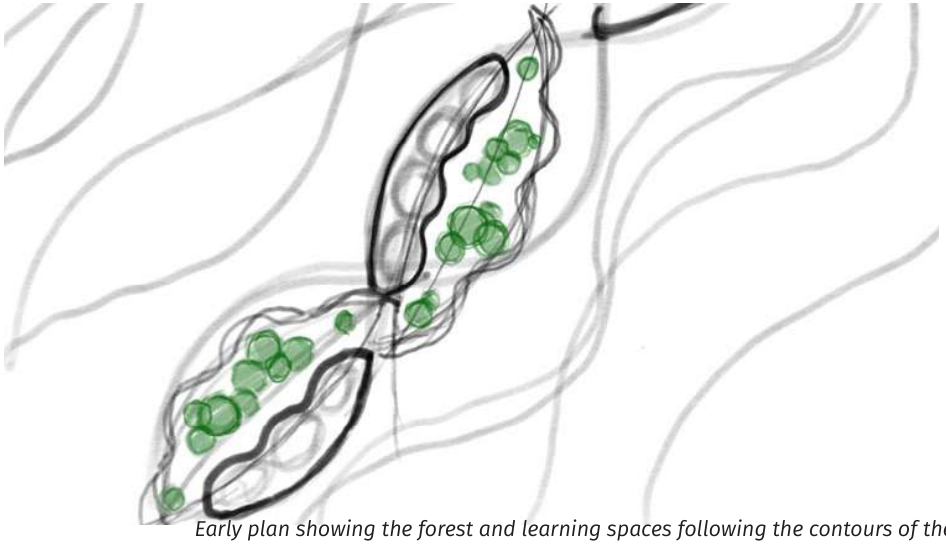




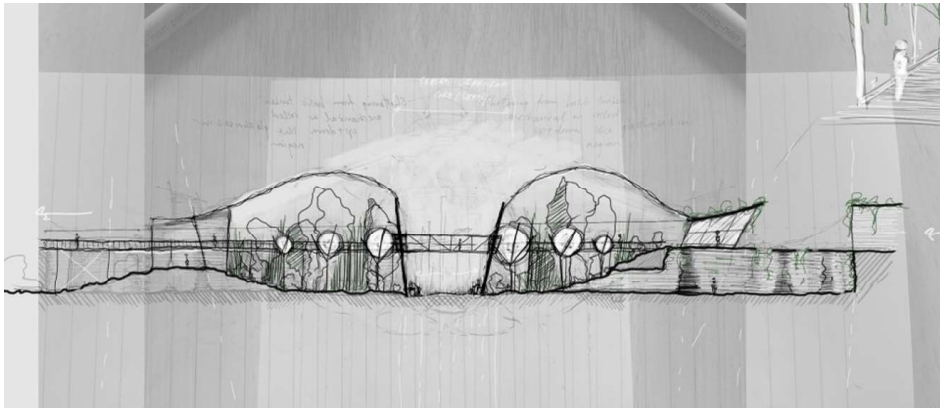



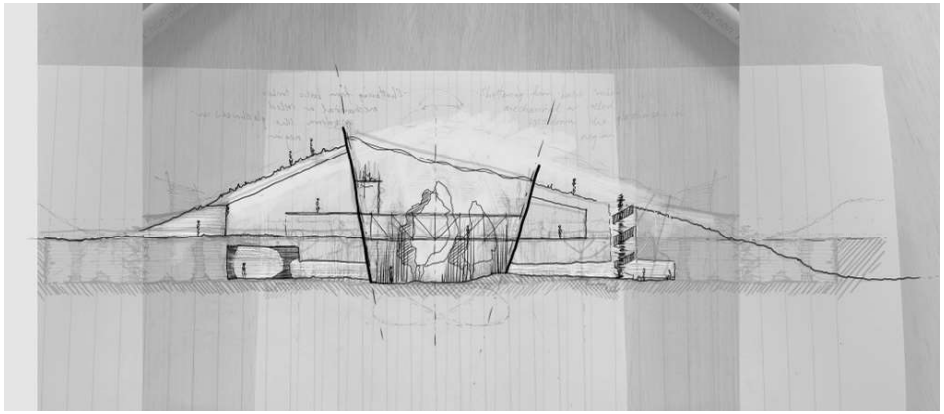

9.3.3 Option 3 - Carving through the Landscape

- A venue which expresses the coal mining past of the site by carving through the landscape
- Exposing the strata of the site
- Built into the land to maximise thermal storage following the form of the landscape
- Linear forest creating a continuous connection with nature as you journey through the building



Early plan showing the forest and learning spaces following the contours of the site

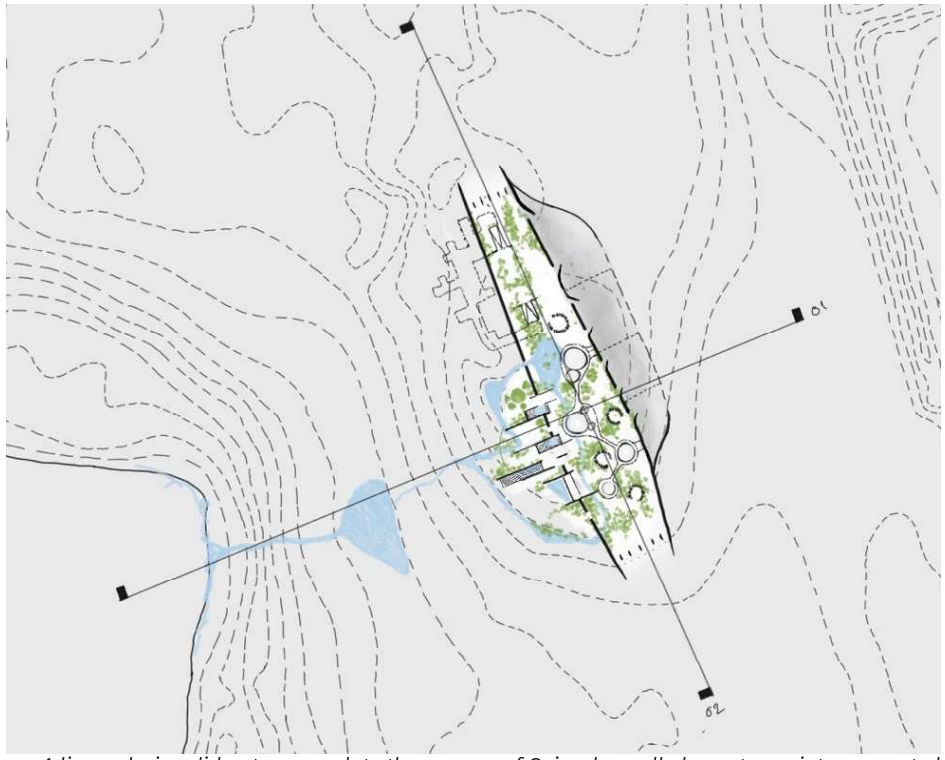




Early sketches

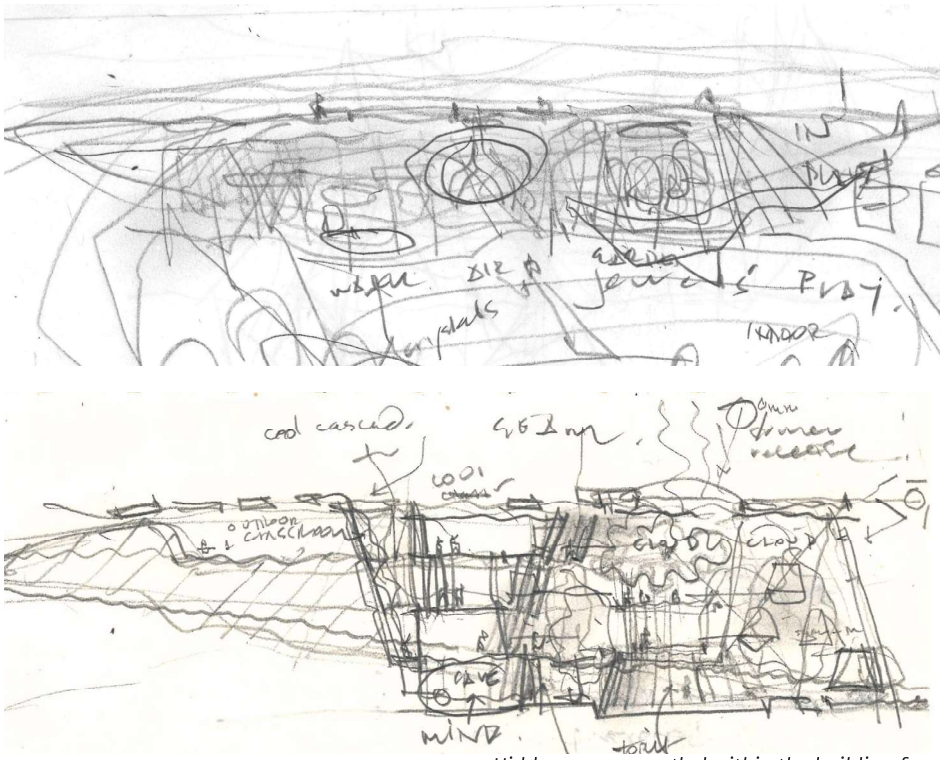
9.3.3 Option 3 - Carving through the Landscape

Plan diagram



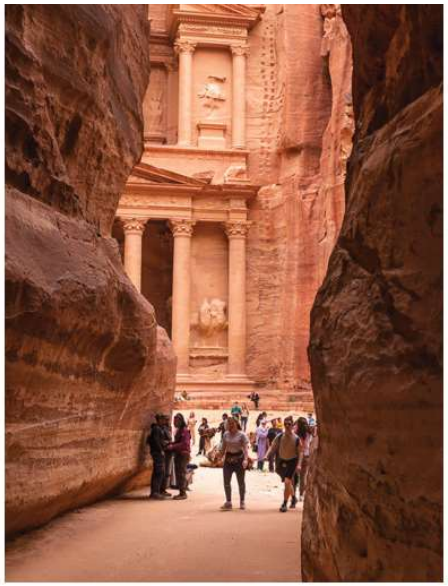
A linear design did not encapsulate the essence of Gaia where all elements are interconnected

South facade view



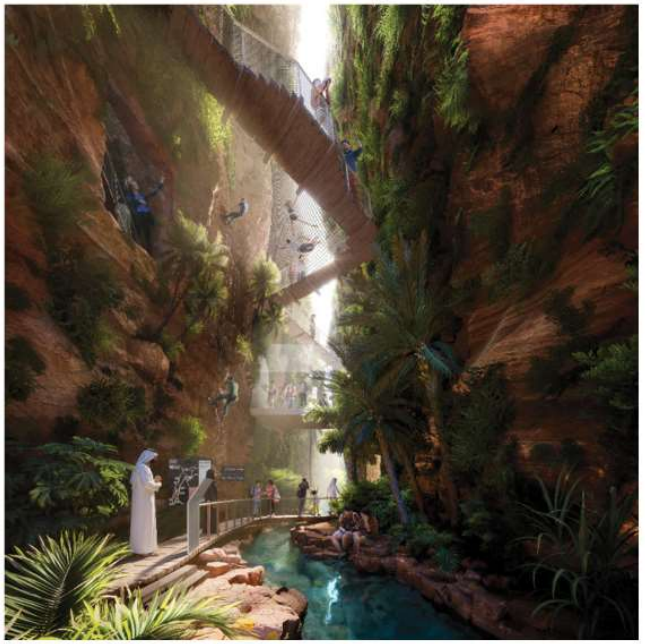
Hidden spaces nestled within the building face

9.3.3 Option 3 - Carving through the Landscape



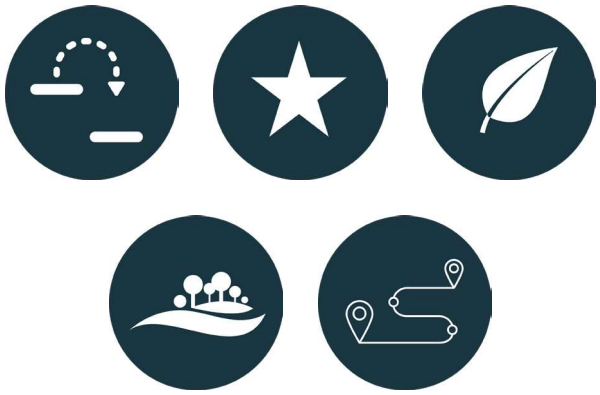


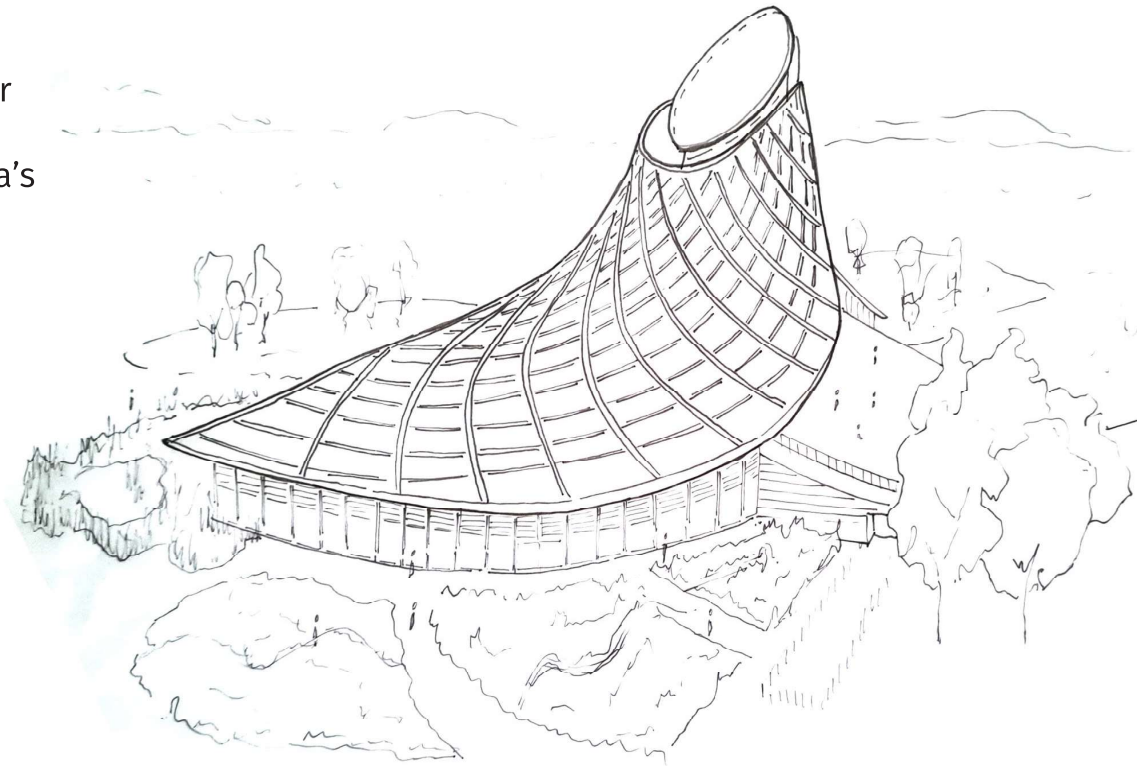



9.3.4 Options Appraisal

Emerging from the Landscape

Option two responds to all the design drivers and was selected as the preferred option to take forward. A clear expression of the movement from black to green, the Silesia Project will become an exciting symbol of Karvina's regeneration.

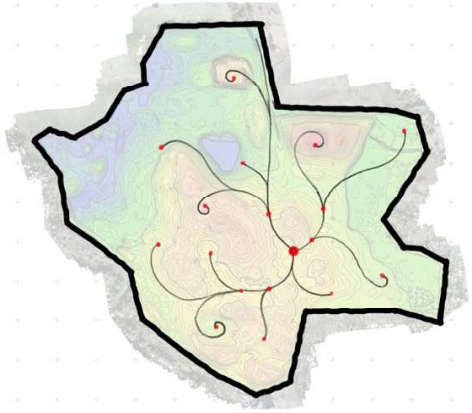




Architectural Design

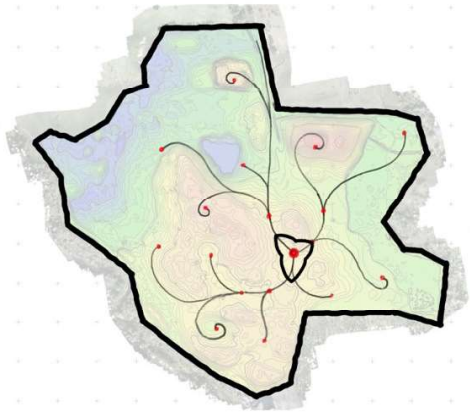
9.4 Design Narrative

1. A **network of learning** spaces



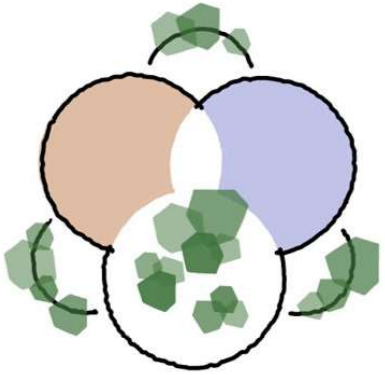
The venue is more than a building, it is a living breathing landscape which immerses its inhabitants and visitors in nature. The building and its surroundings exist in harmony to create a destination like no other.

2. The Gaia at the **heart of the network**



The Gaia building lies at the centre of the network responding to the land and the masterplan, connecting all elements. It is the beating heart of the campus.

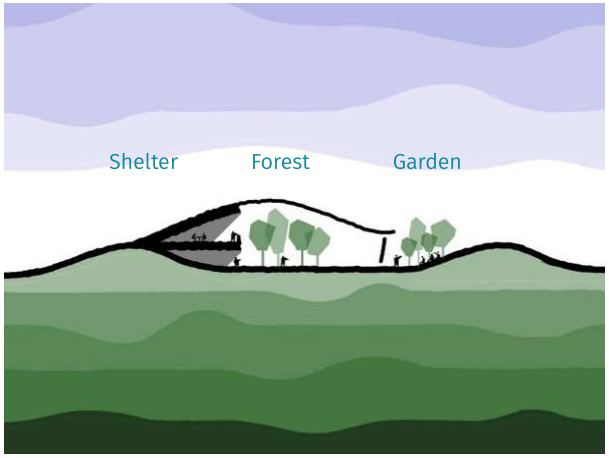
3. A **unique learning environment**



Responding to the Thematic Brief, The Gaia is built around different ecosystems which create varied and vibrant learning environments connected via the central forest.

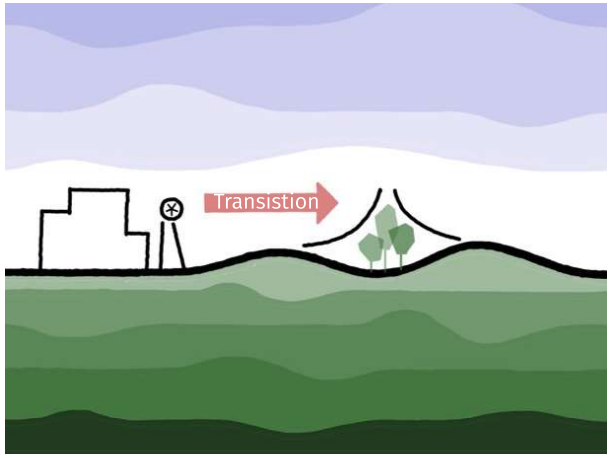
9.4 Design Narrative

4. A building **integrated within the landscape**



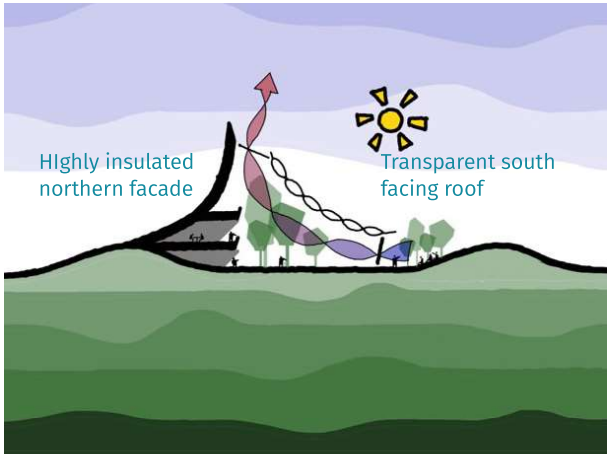
A design which responds to the way in which the site has evolved.

5. A landmark of **sustainable transition**



A striking form which emerges from the landscape, the ultimate representation of the green future, an icon of regenerative design and the regeneration of Karvina.

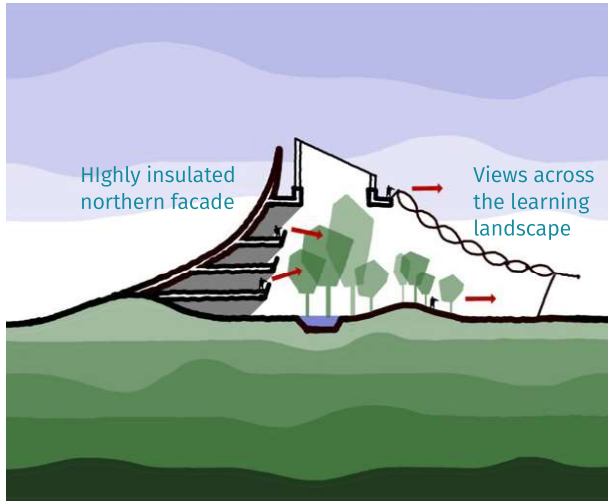
6. **Form follows physics**



The form of the building drives natural ventilation, creating a healthy environment for strong plant growth.

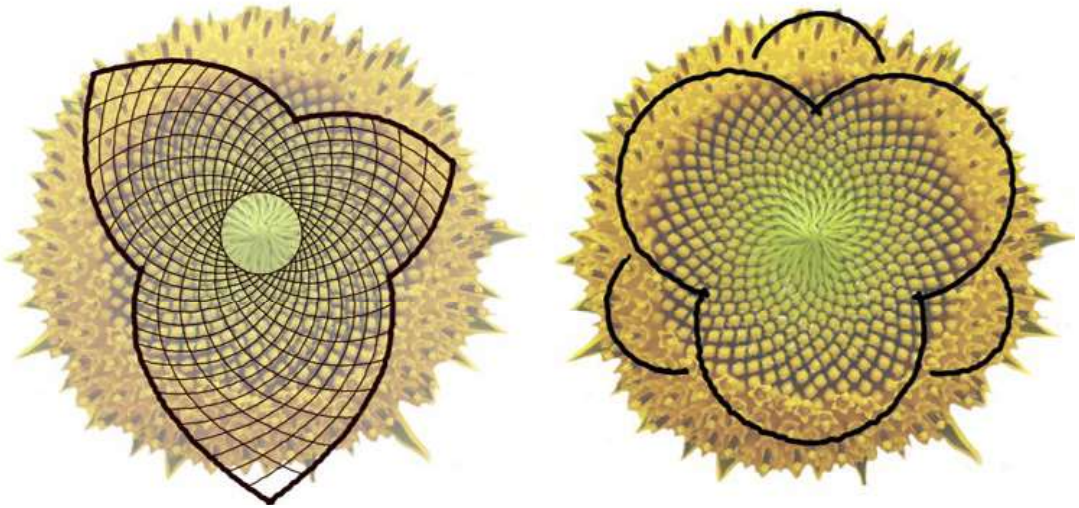
9.4 Design Narrative

7. Multi level **immersion in nature**



Learning immersed in nature at multilevels, creating a vibrant and dynamic experience. A building which connects with the outside world in all directions and at all levels.

8. A form inspired by the **natural geometry of spiral phyllosaxis**



The geometry found in plants determines the form of the building. An expressed timber grid shell structure is both beautiful and efficient.

9.5 Schedule of Accommodation

The spatial requirements for The Gaia have been developed over the feasibility study to respond to the emerging thematic brief and education programme. The key areas identified are as follows:

- Forest
- Water
- Soil
- Geology
- Air

Emerging spatial requirements to scale

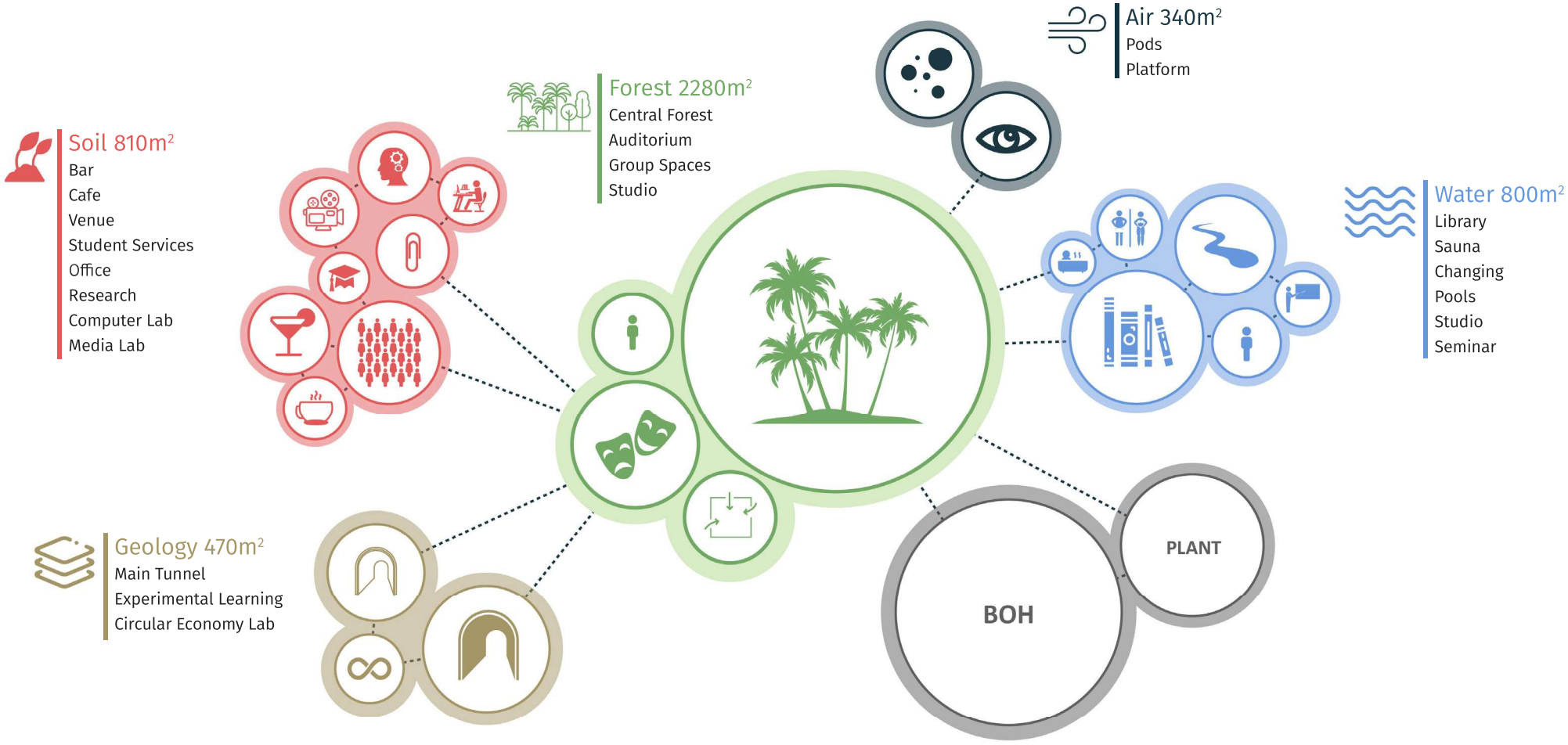
9.5 Schedule of Accommodation

The following schedule of accommodation has been developed according to the current scheme for The Gaia building and the wider campus. Further analysis will be required when the project starts its next phase of design to understand in more detail specific area requirements.

1.2	SPACE	QUANTITY	INTERNAL AREA (SQM)
	The Gaia		
	Learning space : Forest		
	Central forest	1	1,800
	Auditorium	1	200
	Group spaces	4	160
	Studio	1	120
	Forest total		**2,280**
	Learning Space : Geology		
	Main Tunnel	1	200
	Experimental laboratories	2	180
	Circular economy lab	1	90
	Geology total		**470**
	Learning Space : Soil		
	Bar	1	125	125
	Student services	1	50	50
	Office	1	100	100
	Research	1	100	100
	Computer lab	1	70	70
	Media lab	1	90	90
	Soil total			**810**
	Learning Space : Water			
	Library	1	340	340
	Sauna	1	40	40
	Changing	1	80	80
	Pools	1	190	190
	Studio	1	90	90
	Seminar	2	30	60
	Water total			**800**
	Learning Space : Air			
	Pods	5	30	150
	Platforms	1	150	150
	Air total			**340**

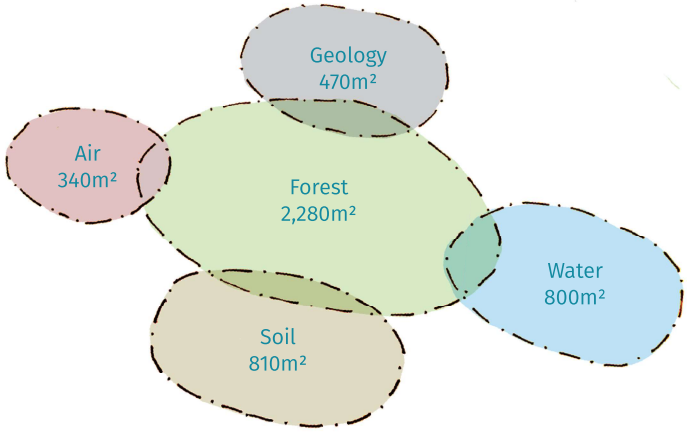
Subtotal	**4,700**
BoH 20% TBC	**980**
Plant 6% TBC	**390**
Total	**6,070**

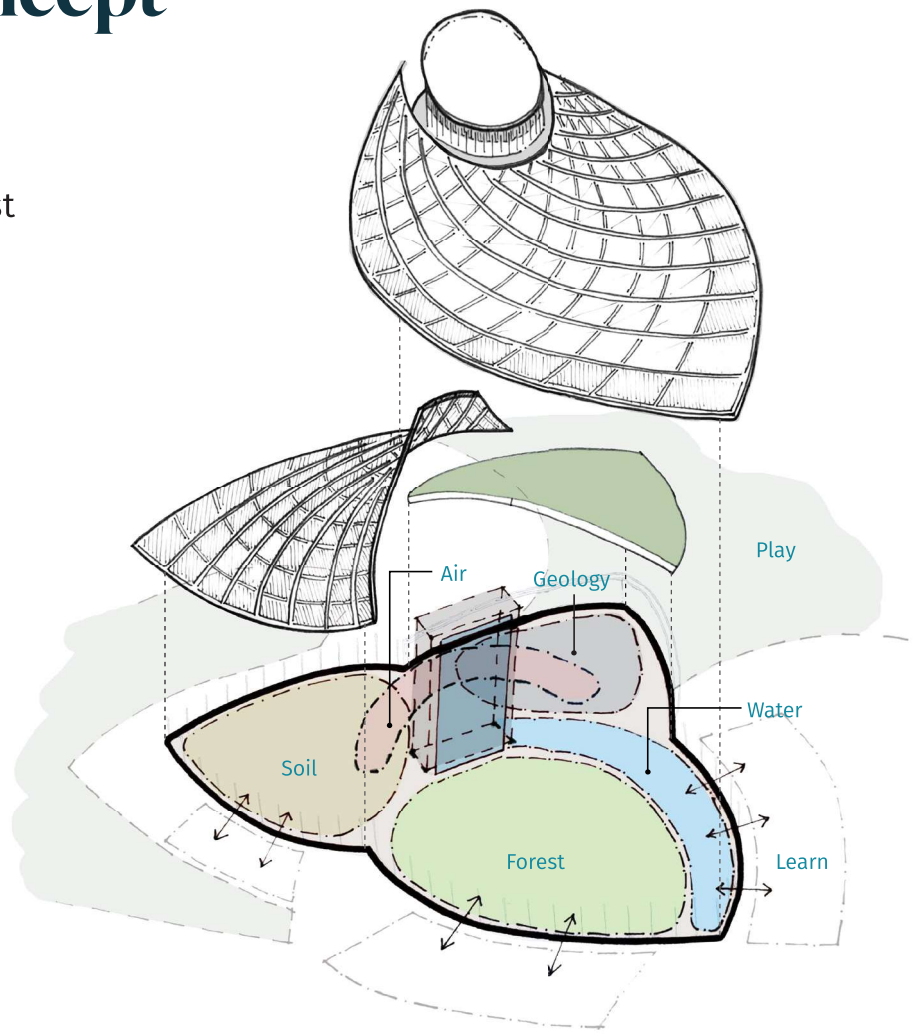
9.6 Adjacency Diagram



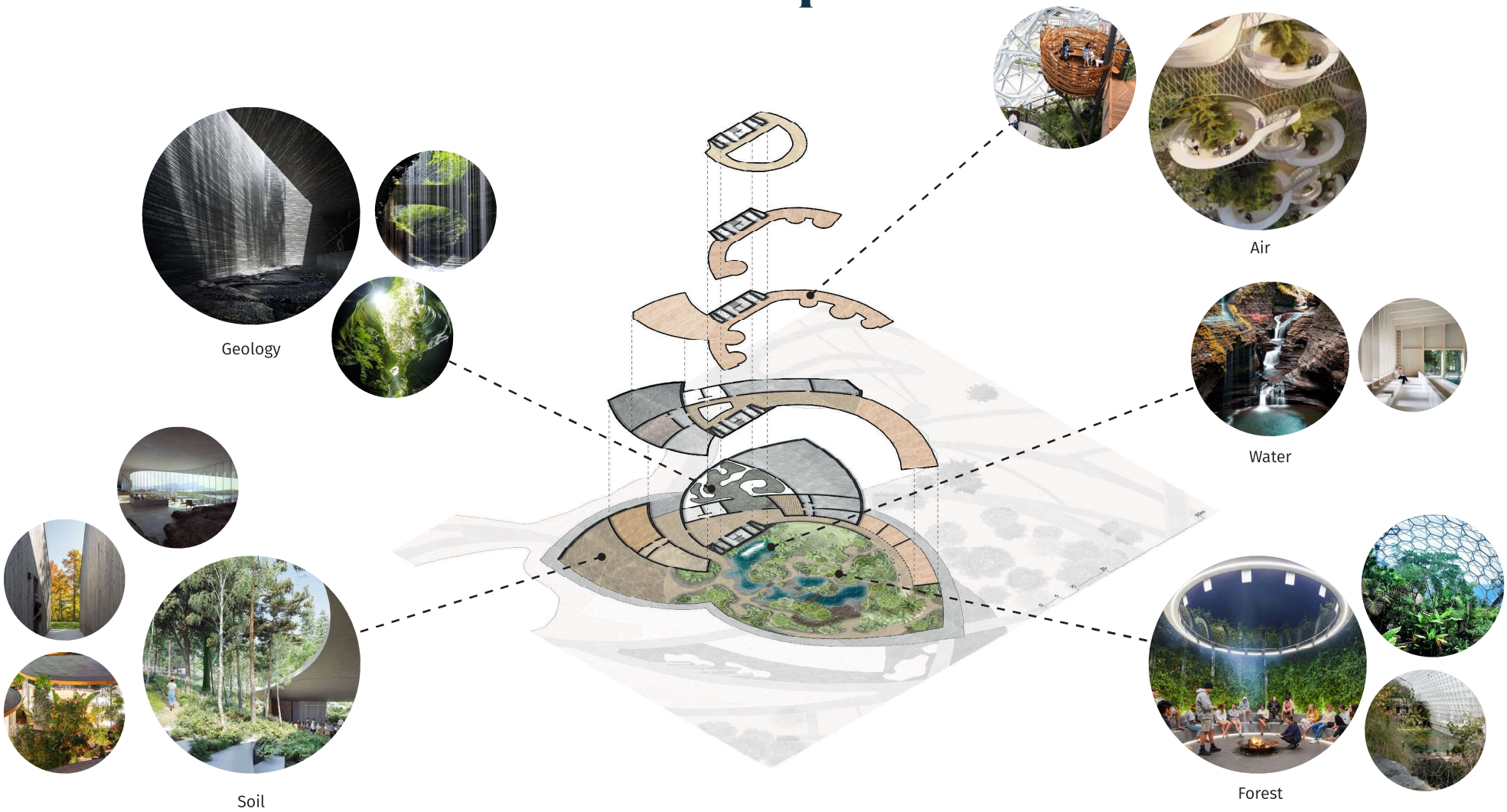
9.7 Integration of Thematic Concept

The architectural design responds to the thematic experience: everything is connected and everything comes back to the forest. The design of the building reinforces the message that humans must learn to live in harmony with nature and ultimately the planet. When you are in The Gaia you are ‘in nature’.





9.8 A Series of Interconnected Spaces



9.9 Ground Plan

Key

01 Venue (200m²)
02 Bar (100m²)
03 Cafe (115m²)
04 Office (75m²)
05 Student Services (50m²)
06 BOH (110m²)
07 Plaza (150m²)
08 Vertical Circulation Core (75m²)
09 WC (50m²)
10 Circular Economy Lab (55m²)
11 Geology Main Tunnel (250m²)
12 Plant (355m²)
13 Sauna (40m²)
14 Changing (100m²)
15 Seminar (60m²)
16 Studio (90m²)
17 Pools (200m²)
18 Auditorium (200m²)
19 Central Forest (1460m²)
20 Forest Group Spaces (90m²)
21 Entrance Tunnel (65m²)

9.9 First Floor Plan

Key

01 Experimental Laboratories (180m²)
02 Computer Lab (80m²)
03 Media Lab (85m²)
04 Plaza (165m²)
05 WC (50m²)
06 Research (100m²)
07 Library BOH (50m²)
08 Vertical Circulation Core (75m²)
09 Auditorium (200m²)
10 Library (330m²)

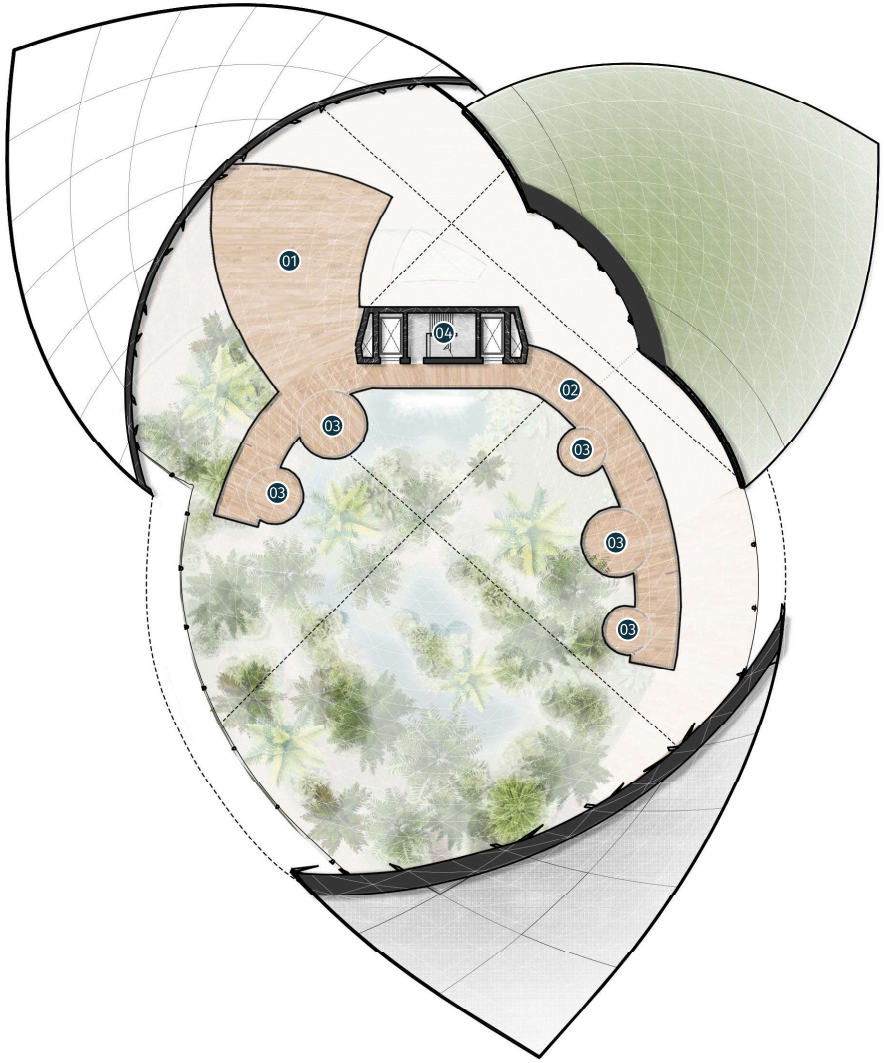
0m 5m 10m 20m 50m

1 : 750 @ A4

9.9 Second Floor Plan

Key

01 Forest Studio (200m²)
02 Air Walkway (190m²)
03 Air Pods (110m²)
04 Vertical Circulation Core (75m²)



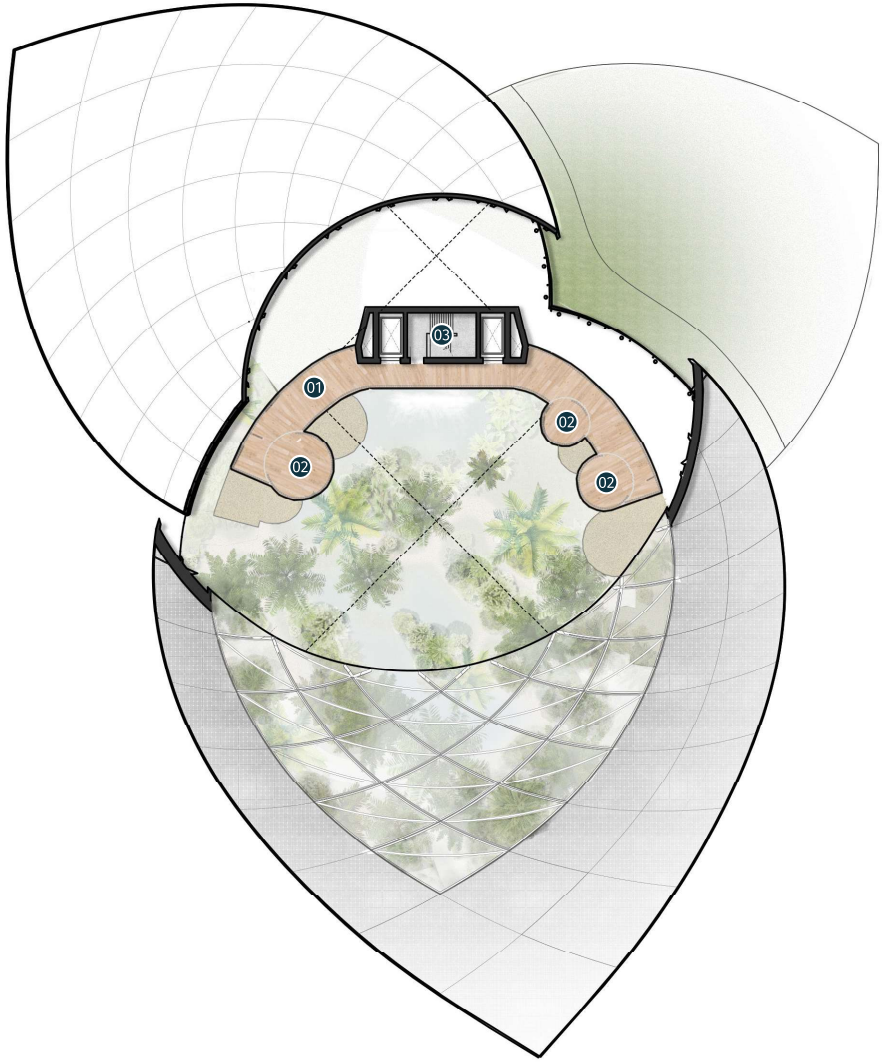
0m 5m 10m 20m 50m

1 : 750 @ A4

9.9 Third Floor Plan

Key

01 Air Walkway (130m²)
02 Air Pods (65m²)
03 Vertical Circulation Core (75m²)



0m 5m 10m 20m 50m

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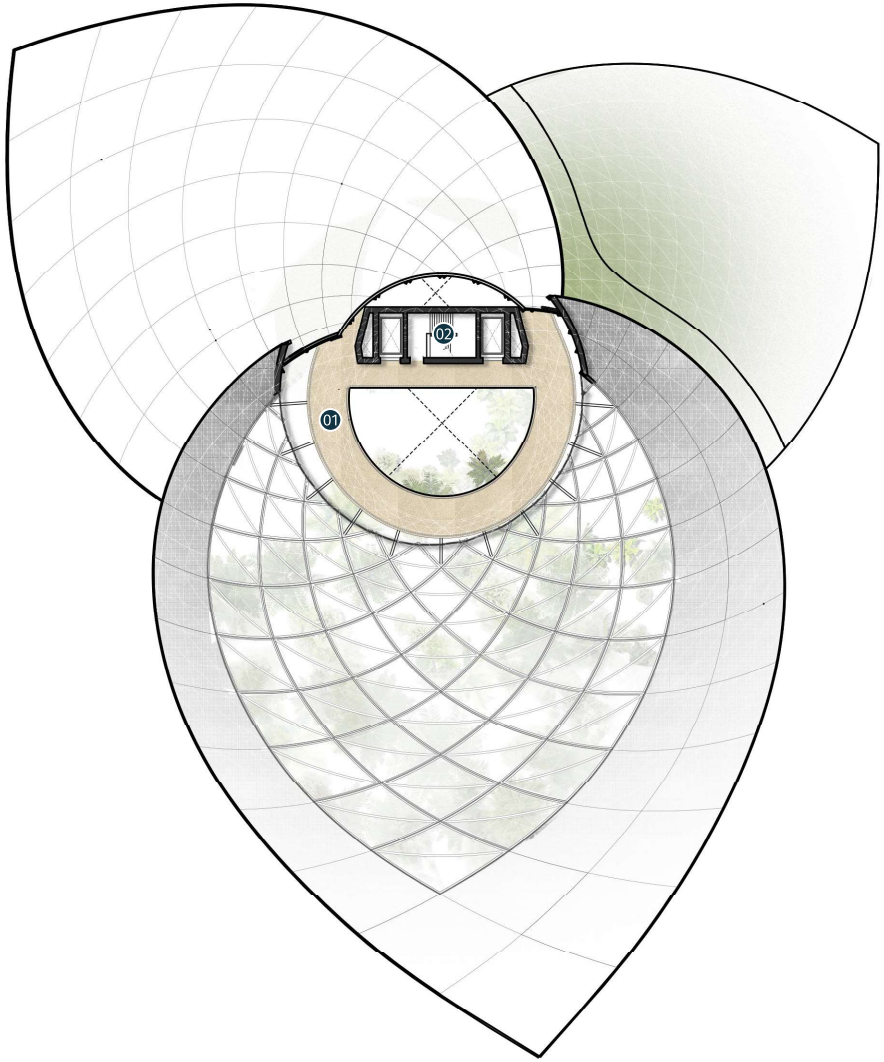
9.9 Fourth Floor Plan

Key

01 Viewing Deck (40m²)

02 Vertical Circulation Core (75m²)



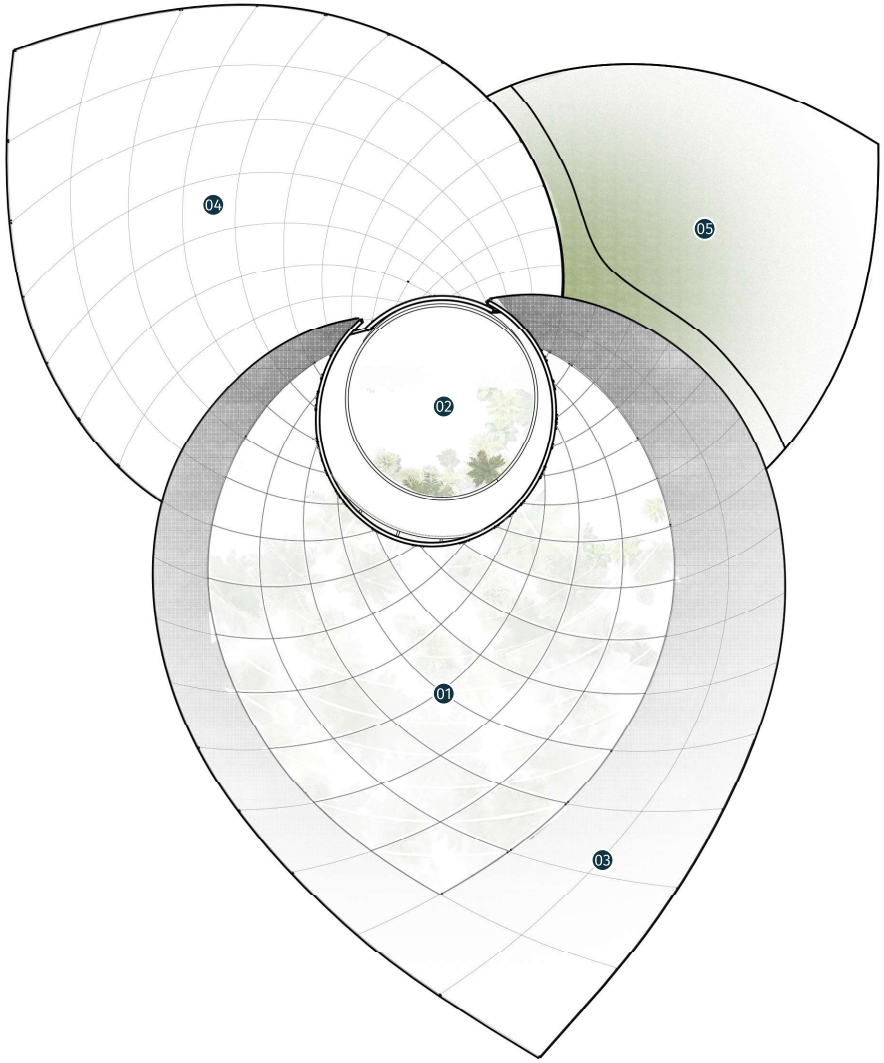
0m 5m 10m 20m 50m

1 : 750 @ A4

9.9 Roof Plan

Key

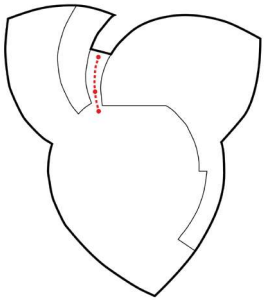
01 ETFE Cladding
02 Glazing
03 Solar Panels
04 Aluminium Panels
05 Green Roof



0m 5m 10m 20m 50m

1 : 750 @ A4

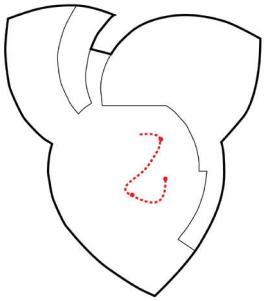
9.10 A Journey Through The Gaia



Visitors enter the building through the entrance cave formed by the elements of soil and geology.

As they approach the end of the entrance route, a lush bright forest comes into view and the sound of falling water increases.

The visitor steps out of the compressed entrance into a bright voluminous space beneath the dramatic central roof glazing adjacent to the waterfall.

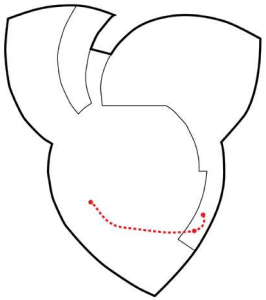


A natural amphitheatre is nestled against the backdrop of geology adjacent to the falling water.

Clearings and nooks appear, supporting a range of learning activities surrounded by nature.

Deep in the centre of the forest, the dense tree cover creates an immersive natural experience.

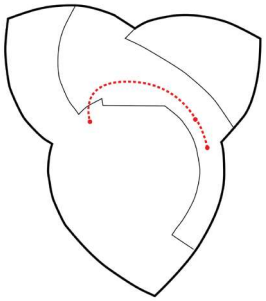
9.10 A Journey Through The Gaia



Throughout the forest, openings provide views through the trees to the waterfall.

Study spaces surrounding the forest create inspiring learning spaces and blur the boundary between the internal and external landscapes.

The library opens to the treetop canopy, creates an intimate learning space and provides a unique and peaceful experience.

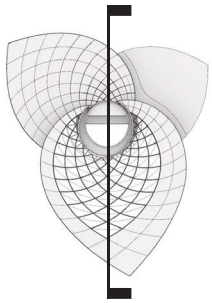


The natural amphitheatre creates a connection between the ground and first floor.

Unique learning pods surround the waterfall, appearing to float in the air above the forest.

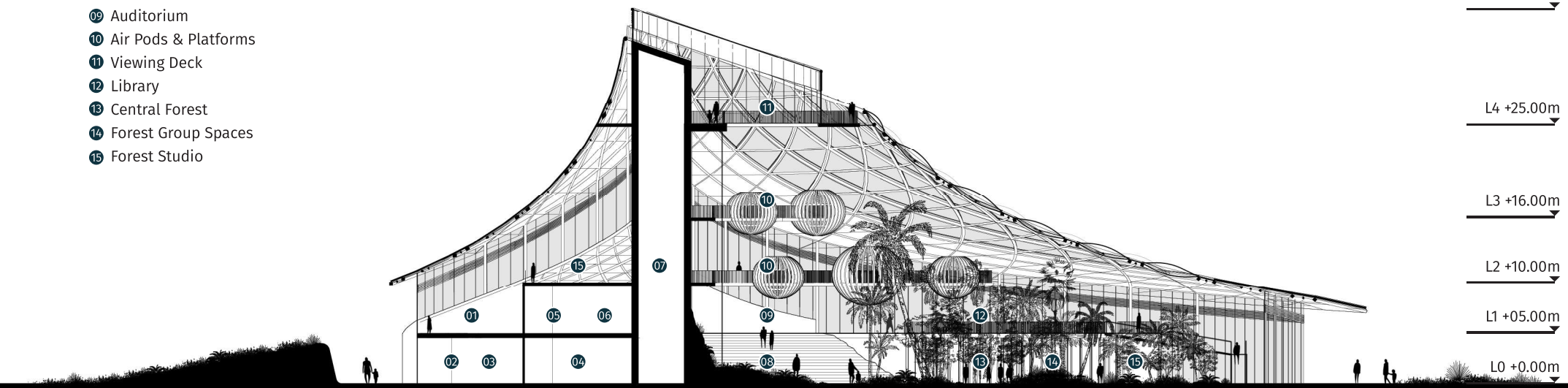
These aerial learning spaces provide a spectacular vantage point from which to view the tree canopy below.

9.11 Cross Section



Key

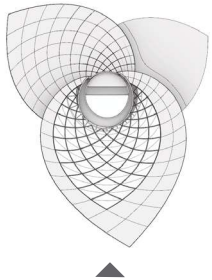
01 Experimental Laboratories
02 Venue
03 Bar
04 Cafe
05 Computer Lab
06 Media Lab
07 Vertical Circulation Core
08 Pools
09 Auditorium
10 Air Pods & Platforms
11 Viewing Deck
12 Library
13 Central Forest
14 Forest Group Spaces
15 Forest Studio



0m 5m 10m 20m 50m

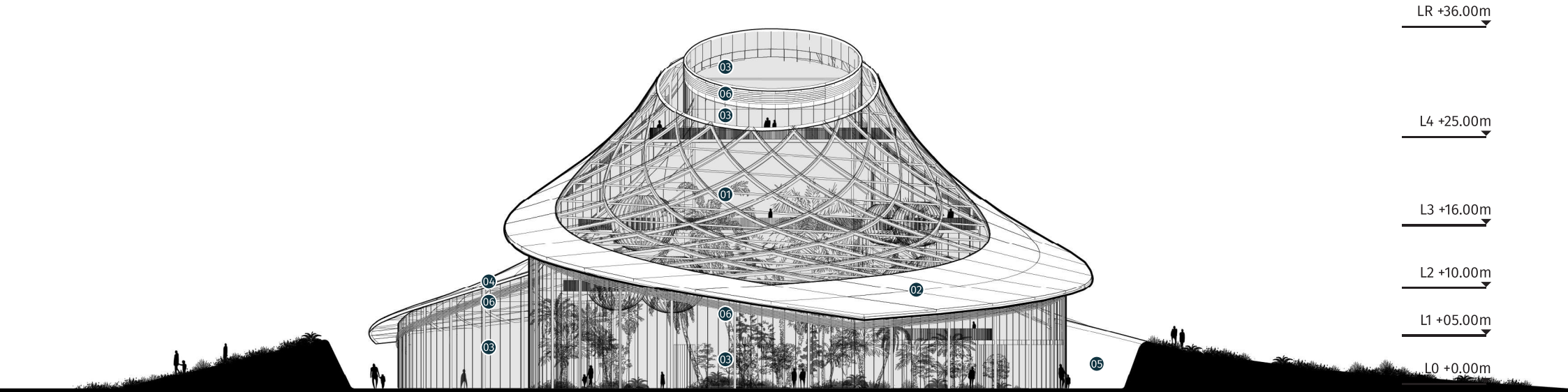
1 : 500 @ A4

9.12 South Elevation



Key

01 ETFE Cladding
02 Solar Panels
03 Glazing
04 Aluminium Panels
05 Rammed Earth Walls
06 Louvres



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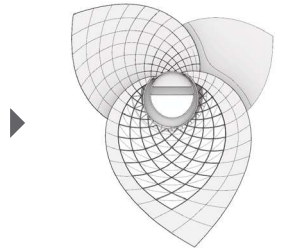
9.12 West Elevation



Key

01 ETFE Cladding
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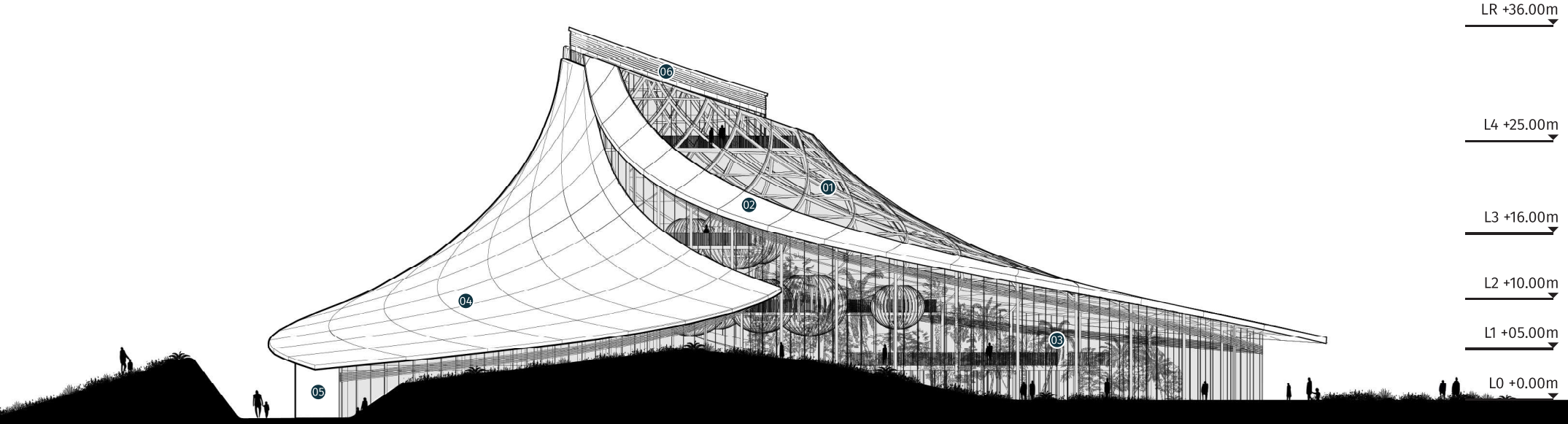


0m 5m 10m 20m 50m

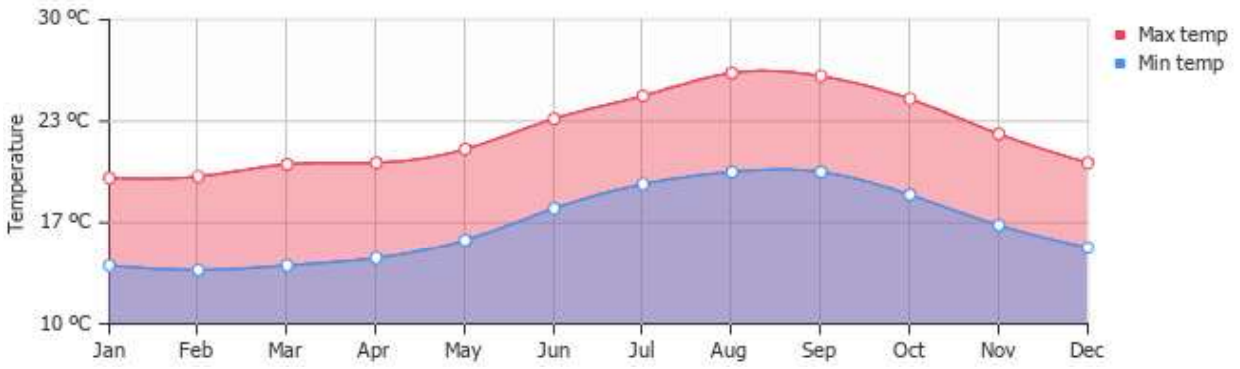
1 : 500 @ A4

Forest Planting Strategy

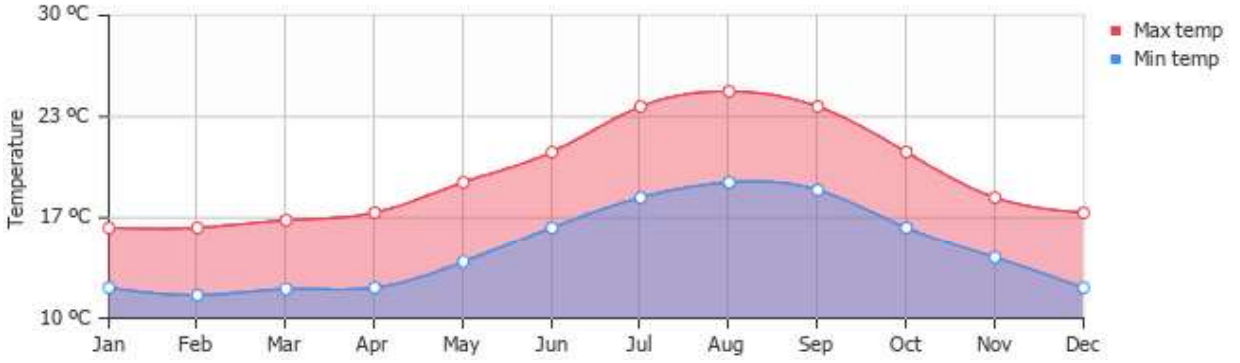
9.13 Internal Climate

It is important that the internal climate of The Gaia minimises the need for winter heating and summer cooling. It is proposed that the temperatures are therefore similar to the Atlantic islands of the Azores or Madeira, which have a mild to warm subtropical climate with minor fluctuations throughout the year. Daily maximum temperatures will range between 16 and 25 °C with a winter night-time minimum of around 10°C for planted areas with soil insulation to mitigate external ground temperatures. During the summer, natural ventilation will moderate the internal temperature for people and plants. Air flow will help the establishment of trees and assist plant health.

During the winter, 'hot spots' with higher temperatures will be created in seating and gathering areas for student and visitor comfort. This will efficiently warm people rather than the volume of the space.



Average min & max temperatures in Funchal, Madeira



Average min & max temperatures in Angra do Heroismo, Portugal

9.14 Forest Plants

The Gaia climate will support a wide diversity of plants from around the world to support the narrative. As in a naturally diverse subtropical woodland and to create a lush and multi-textured experience for people, plants will be arranged to create a canopy, understory and ground cover. Vertical surfaces will also be planted using proprietary vertical planting systems. To give a sense for the look and feel of the Forest planting – images are included.

Plants will be labelled with names, original continent of origin and points of interest. Using QR codes or similar on plant labels, we can 'transport' people to the native habitat of the plants via video or pictures, even augmented reality (AR).

Angraecum sesquipedale (Darwin's Orchid)

Araucaria heterophylla (Norfolk Island Pine)

Asplenium nidus (Bird's Nest Fern)

Banksia integrifolia (Coastal Banksia)

Chusquea gigantea (Striped Bamboo)

Cupressus cashmeriana (Kashmir Cypress)

9.14 Forest Plants

Selected Native Species


Cyathea dealbata (Silver Fern)


Cycas revoluta (Sago Palm)


Cyrtostachys renda (Sealing Wax Palm)


Dawsonia superba (Large Moss)


Dicksonia squarrosa (Tree Fern)


Elegia capensis (Horsetail Restio)


Equisetum giganteum (Giant Horsetail)


Guadua angustifolia (Giant Bamboo)


Hedychium gardnerianum (Kahili Ginger)


Illicium simonsii (Star Anise)


Macrozamia moorei (Cycad Palm)


Magnolia grandiflora (Southern Magnolia)


Michelia figo (Banana Shrub)


Nymphaea nouchali (Waterlily)


Oceaniopteris gibba (Miniature Tree Fern)


Protea cynaroides (King Protea)


Tillandsia usneoides (Spanish Moss)


Wollemia nobilis (Wollemi Pine)

9.15 Plant management and maintenance

It is important to manage and maintain the plants professionally to keep the Forest healthy and free from pests and diseases. While Eden Project have experience of managing a tropical rainforest and Mediterranean environment, each diverse plant community is different which offers opportunity to carry out practical research into the best methods for this site. The skills and experience of MendelU will be valuable here.

From experience in Cornwall, we know that ensuring plant health before planting is critical. In an enclosed environment – away from natural predators – pest and diseases can affect the health and appearance of plants. Quarantine prior to planting is important.

Re-circulating biological waste from plant cultivation is an important part of sustainable management and a demonstration of circular systems. Some leaves will fall onto the soil surface and decompose naturally. Other organic material e.g. prunings, extra fallen leaves etc. from inside The Gaia would be taken outside for composting and then returned to 'mulch' and 'feed' the soil. The Maintenance Team would be effectively speeding up the decomposition process that would happen naturally. If there are diseased plants, it is likely that regulation would require any organic waste to be burned or buried to prevent damage to outdoor ecosystems.

Environmental Considerations

9.16 Regenerative Design

Beyond Sustainability

The Silesia Project will be an exemplar of regenerative design. The design will go beyond being sustainable and will give back to the natural world.

Conventional Design
Minimum Legal Standards

Sustainable Design
Neutral Harm

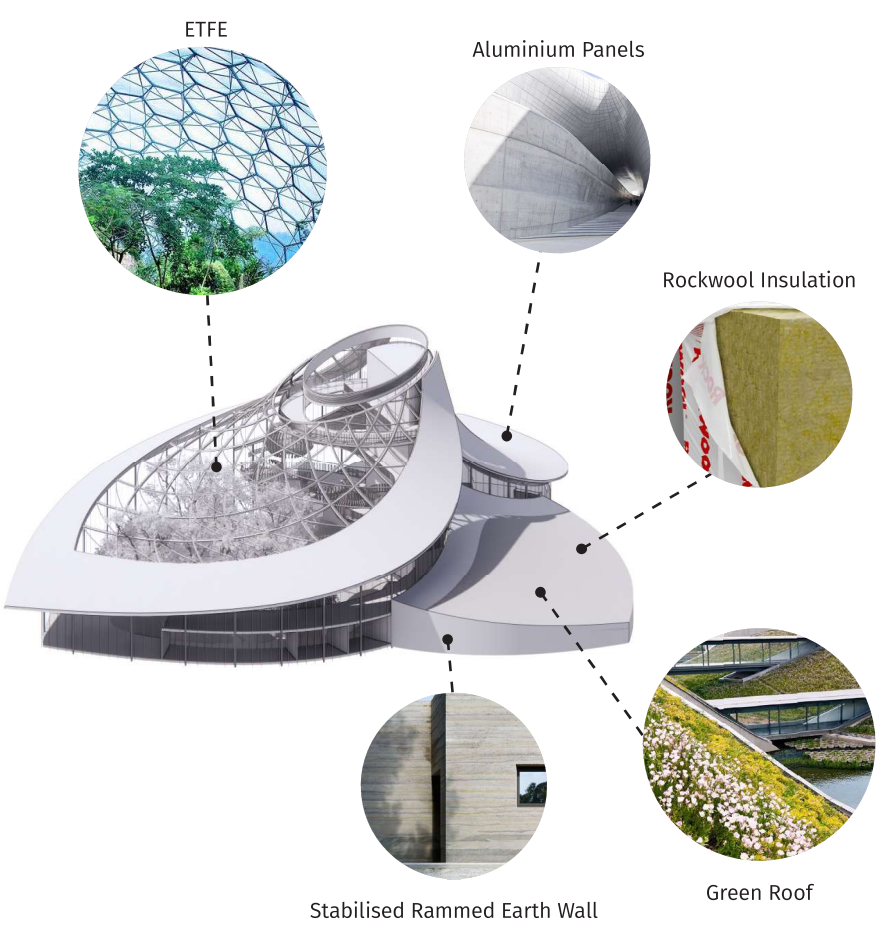
Regenerative Design
Gives Back to the Environment

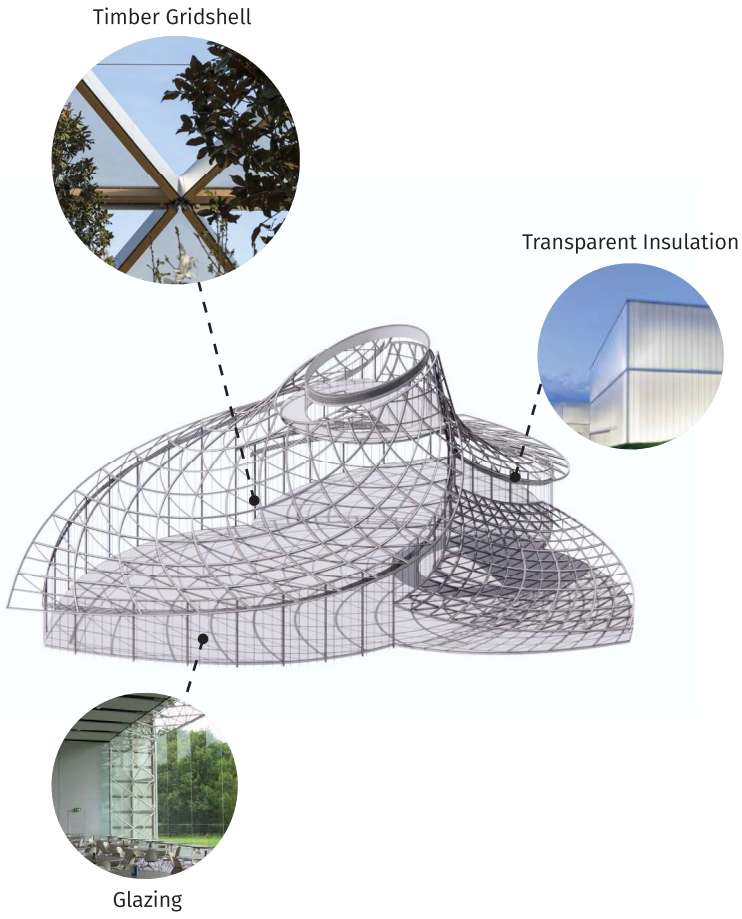
The Building Life Cycle

9.17 The Building Envelope

Low Embodied Carbon

As far as possible, all materials chosen for The Gaia building will have low embodied carbon and will sourced locally.



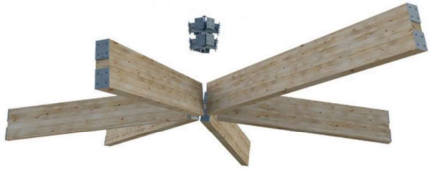


9.17 Building Materials

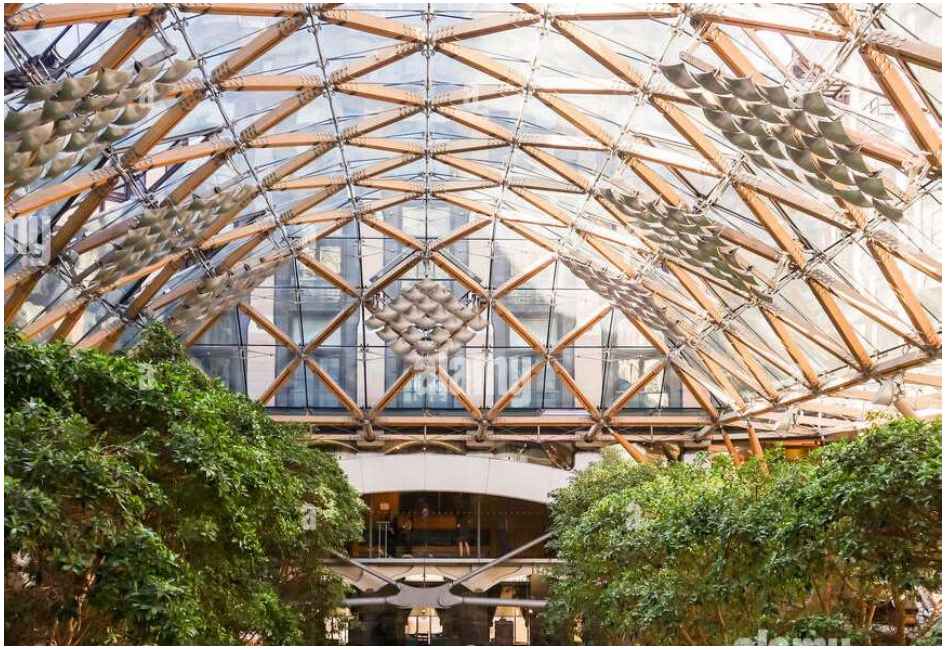
Timber Gridshell

The petal shaped roofs are formed from a timber gridshell. The efficiency of the natural form allows the roof to be lightweight while providing shelter from the elements.

- Timber has **low embodied carbon**
- **Responsibly sourced** materials
- **Efficient** material use



Minimise Waste and Maximise Use of Recycled Components



Portcullis House - Hopkins

9.17 Building Materials

ETFE Cushions & Solar Shading

ETFE cushions on the South petal will flood the forest with natural light, encouraging healthy plant growth and creating an inspiring biophilic environment.

- **Lightweight alternative** to glazing – approximately **1% the weight of glass**
- Has **high translucency** with 95% of the light transmission of glass
- Fire rated to ASTM E84 Class A with natural **fire spread prevention**

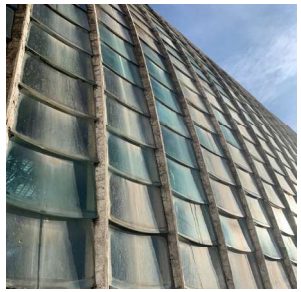
Crossrail Station- Fosters

Eden Cornwall - Grimshaw

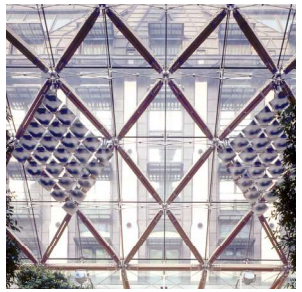
Minimise Waste and Maximise Use of Recycled Components

Taking inspiration from the timber shutters on the orangery at Lednice Palace, we propose a low tech solar shading mechanism. Rather than having a fixed solar shade, as shown on Portcullis House, we propose the use of opaque panels that can be removed or fixed to the timber gridshell as needed.

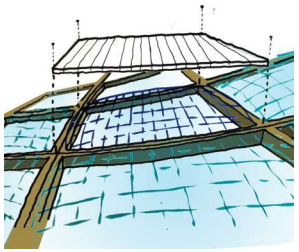
- Can **adapt** to seasonal requirements
- Is easily removed and fixed
- Requires **little maintenance**



Lednice Palace



Portcullis House - Hopkins



9.17 Building Materials

Stabilised Rammed Earth (SRE)

Reflecting the mining history of the site, we propose the use of SRE for the entrance. The SRE will represent the seams of strata in the ground, echoing the mining past of the area.

Minimise Waste and Maximise Use of Recycled Components

- SRE is 5-10% cement to ensure **strength and durability**
- Formwork can be **reused indefinitely** unlike concrete
- Fire rated to ASTM E84 Class A with natural **fire spread prevention**

Ajijic - Tatiana Bilbao

Loam Clay Earth - Martin Rauch

Nk'Mip Desert Cultural Centre

9.17 Building Materials

Green Roof

The north-east petal is designed as a green roof to promote biodiversity. Activating the roof will provide environmental, social and well-being opportunities.

Minimise Waste and Maximise Use of Recycled Components

- The sedums, herbs, grasses and host plants in the green roof **promote the habitat** of birds, butterflies and insects
- The green roof will absorb water, and create a **rainwater buffer**
- Green roofs **last up to three times as long** as uncovered roofs

Leeds Skelton Lake

California Academy of Sciences

GIG Campus

9.17 Building Materials

Material Sourcing

Where feasibile, all materials will be sourced as locally as possible. Steel, timber, rockwool and local stone will be used for the roof structure, thermal insulation and floor finishes.

Minimise Carbon in Energy Supply and Value Chain

Timber
30km

Třinecké železárny
Steel 20km

Tesin Limestone
30km

Lipov Marble
140km

Light Silesian
Granite 150km

Rockwool
Insulation 20km

Tesin Sandstone
30km

Glulam
40km

Masonry
90km

Solid Wood Panels
100km

Supikovice Marble
140km

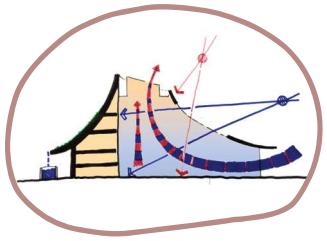
Flat Construction
Timber 150km

Sand-line masonry
Limestone 200km

Silesian Granite
220km

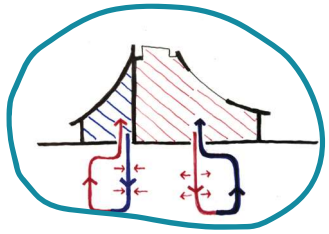
Locally Sourced — Distant

9.18 Energy Considerations



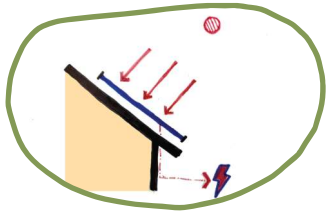
Passive Design

Passive design allows the building to regulate heat and light without mechanical intervention.



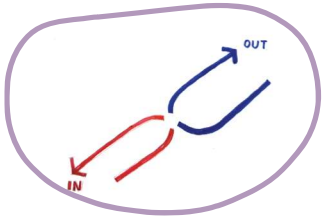
Ground Source Heat Pumps

The building utilises a GSHP to provide cooling to the Forest and heating to the learning spaces. The GSHP will be displayed to the public in an interactive exhibition to encourage engagement with low carbon technologies.



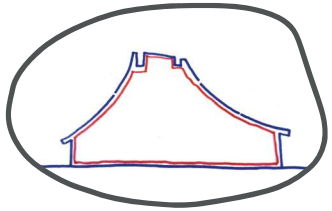
Solar Power

The south petal has a large area of PVs, providing clean, renewable energy to The Gaia building. In a later stage, PVs could be introduced as solar shaders for the edible landscape and car park.



Heat Recovery (MVHR Systems)

An MVHR system will compliment the passive cooling in the forest. Using this system will substantially reduce the energy lost through the north facade and roof.



Thermal Envelope

The extremes of summer and winter temperatures in Karvina give special significance to insulating the building.

9.18 Energy Considerations

This development will be an exemplar net zero or net positive development.

The energy system will follow the Lean > Clean > Green approach as outlined below.

This process looks to maximise passive design opportunities with the heating and cooling provided in a clean and energy efficient way. Renewables are then used to offset the carbon produced in the provision of electrical power for the heat source.

Figure: Design Hierarchy for Energy Efficiency

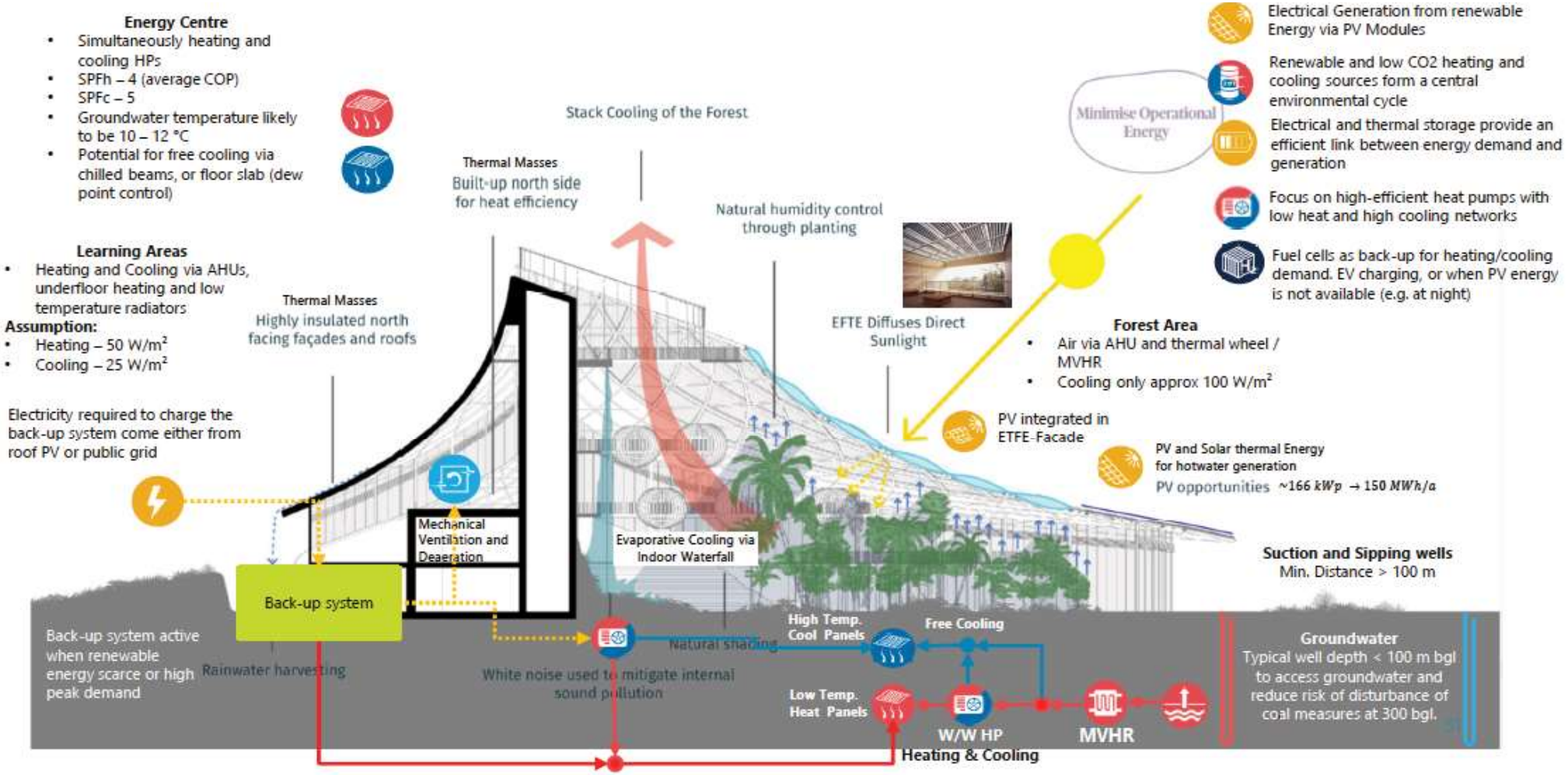
Energy Concept

A mix of low carbon technologies are to be considered for the site, these are shown in the figure below and include:

- Electrical generation from renewable energy via PV Modules
- Renewable and low CO2 heating and cooling sources form a central environmental cycle
- Electrical and thermal storage provide an efficient link between energy demand and generation
- Focus on high-efficient heat pumps with low heat and high cooling networks
- Fuel cells as back-up for heating/cooling demand. EV charging, or when PV energy is not available (e.g. at night)

Following review of the borehole data, the ‘cover formations’ strata is termed marl. The logs also contain a series of pump tests at varying depths which indicate that water is present and could in theory be used as part of a ground source energy system subject to appropriate investigations / testing.

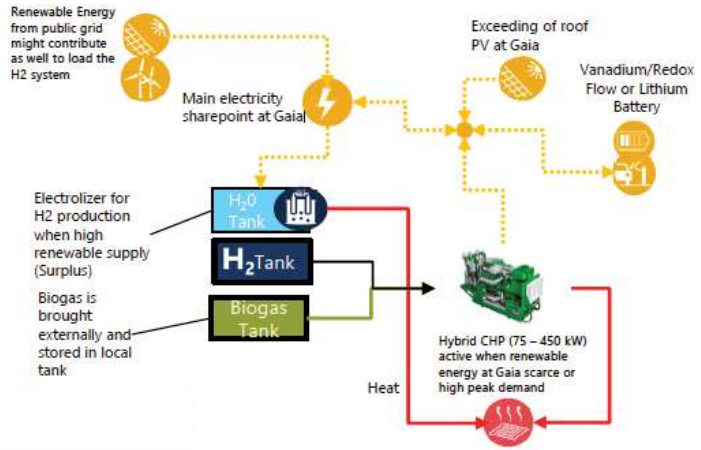
9.18 Energy Considerations - Main Energy Concept



9.18 Energy Considerations - Backup System Subvariants

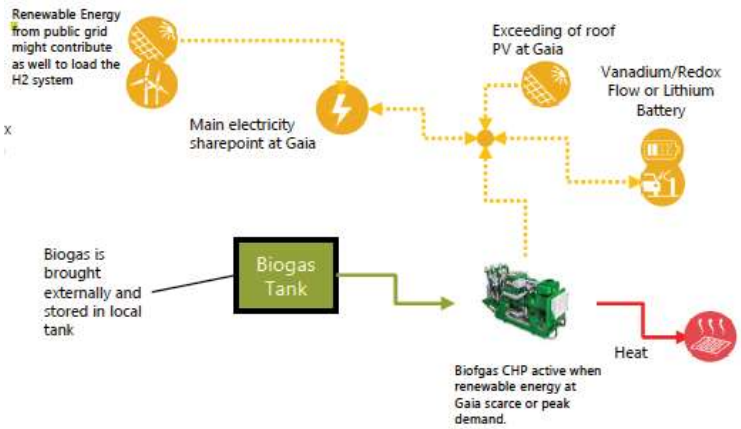
1.1 Green H2 + Biogas + Hybrid CHP

- Exceeding of roof PV energy at Gaia's is prioritized to load the H2 system and charge EVs.
- When lack of roof PV energy, H2 and biogas can be used in a hybrid CHP to cover the electricity and heating demand.
- When lack of roof PV energy and H2 system is empty, H2 system must be charged with 100% renewable energy from the grid.
- EVs can act as both as a load and storage. It is flexible as back-up to deliver electricity by accepting energy from other systems and the grid.



1.2 Biogas CHP

- Exceeding of roof PV at Gaia's is prioritize to charge EVs. Otherwise, 100% renewable energy from public grid takes place.
- When lack of roof PV energy, and EVs are not available orempty, biogas CHP is prioritize to cover the electricity and heating demand.



9.18 Energy Considerations

	Space Data				Internal Loads	External Loads	
Space	**Quantity**	**Building Type**	**Internal Area (m2)**	**Sum**	**Electricty Load (kW)**	**Heat (kW)**	**Cooling (kW)**
The Gaia							
Learning Space: Forest - Central Forest	1	Retail	1,00	1,800	288,0	180,0	252,0
Learning Space: Forest - Auditorium	1	Education	200	200	10,0	17,4	20,0
Learning Space: Forest - Group Spaces	4	Education	40	160	8,0	13,9	16,0
Learning Space: Forest - Studio	1	Office	120	120	7,4	8,4	10,4
Forest Total				2,280	313,4	219,7	298,5
Learning Space: Geology - Main Tunnel	1	Residential	200	200	16,0	12,0	14,0
Learning Space: Geology - Experimental Laboratories	2	Education	90	180	9,0	15,7	18,0
Learning Space: Geology - Circular Economy Lab	1	Education	90	90	4,5	7,8	9,0
Geology Total				470	29,5	35,5	41,0
Learning Space: Soil - Bar	1	Restaurant	125	125	28,1	15,0	25,0
Learning Space: Soil - Student Services	1	Office	50	50	3,1	3,5	4,4
Learning Space: Soil – Office	1	Office	100	100	6,2	7,0	8,7
Learning Space: Soil - Research	1	Education	100	100	5,0	8,7	10,0
Learning Space: Soil - Computer Lab	1	Education	70	70	3,5	6,1	7,0
Learning Space: Soil - Media Lab	1	Education	90	90	4,5	7,8	9,0
Soil Total				535	50,4	4,81	64,1
Learning Space: Water - Library	1	Education	340	340	17,0	29,6	34,0
Learning Space: Water -Suana	1	Retail	40	40	6,4	4,0	5,6
Learning Space: Water -Change Rooms	1	Residential	0	0	6,4	4,8	5,6
Learning Space: Water -Pools	1	Office	190	190	11,8	13,3	16,5
Learning Space: Water -Studio	1	Education	90	90	4,5	7,8	9,0
Learning Space: Water -Seminar	2	Education	30	60	3,0	5,2	6,0
Water Total				800	49,1	64,7	76,8
Learning Space: Air - Pods	5	Retail	30	150	24,0	15,0	21,0
Learning Space: Air - Platforms	2	Retail	150	150	24,0	15,0	21,0
Air Total				300	48,0	30,0	42,0
Sub Total Area (w/o rest of The Gaia - BOH & Plant)				4,385	490,4	398,1	522,3
Rest of The Gaia BOH & Plant (6070 m2 - subtotal area)	1	Residential		1,685	538,4	101,1	118,0
Total				6,070	1,028,9	499,2	640,2

Sum	**Electricty Load (kW)**	**Heat load (kW)**	**Cooling load (kW)**	**Comments**
Avg. Heat / Cool load (W / m2)	169,50	82,23	105,48	Considering all of The Gaia Area (6070m2)
Avg. Heat / Cool load (W / m2)	111,85	90,78	119,11	Considering ONLY The Gaia Subtotal Area (w/o BOH & Plant - 4385m2)
Heat / Cooling period (h/y)	3744	1900	900	Assumed yearly hours for heating/cooling can be adjusted according to Eden CZ hot/cool periods
Energy (MWh/y)	3,852,2	948,8	576,22	Considering all of The Gaia Area (6070m2)
Total Energy (MWh/y)	**5,4**			

Benchmark Cool/Heat loads*

Building Type	**Heat load (w/m2)**	**Cool loads (w/m2)**	**Electricity (w/m2)**
Education	87	100,05	50
Office	70	87	62
Retail	100	140	160
Residential	60	70	0
Restaurant	120	200	225

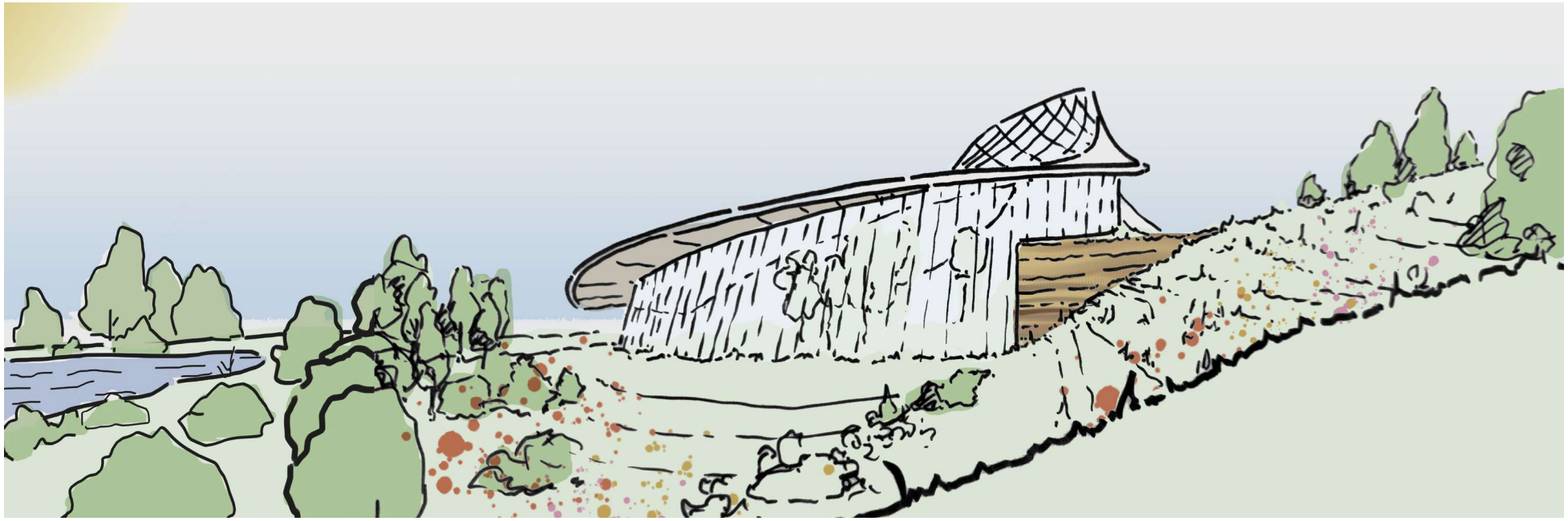
Benchmark according to BSRIA Rule of Thumb

9.19 Water Management

Rain water will be harvested from the roof to use as grey water in the building. Low flow fixtures and smart water storage will minimise water waste, and reed beds in the landscape will filter excess grey water.

Improve On-Site Water Management

Enhance Ecology and Biodiversity



9.20 Resilient and Adaptable

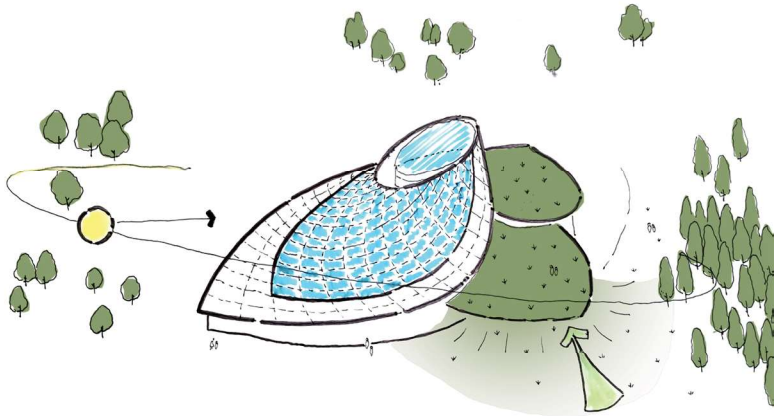
Resilient and Adaptable to Future Change

The Gaia is designed to be adaptable to future changes in the building programme. The open plan study and teaching spaces can change as the building evolves.

9.21 Health and Wellbeing

Through connections to the beauty of the natural world, the Silesia Project is a university building like no other.

- **Connection** to outside world
- Access to **natural beauty**
- **Promoting access and inclusion**
- **Climate, cultural and aesthetic compatibility** with its surrounding
- Choice of **material** which creates a **calmed interior**



Improve Health and Wellbeing

Structural Engineering Considerations

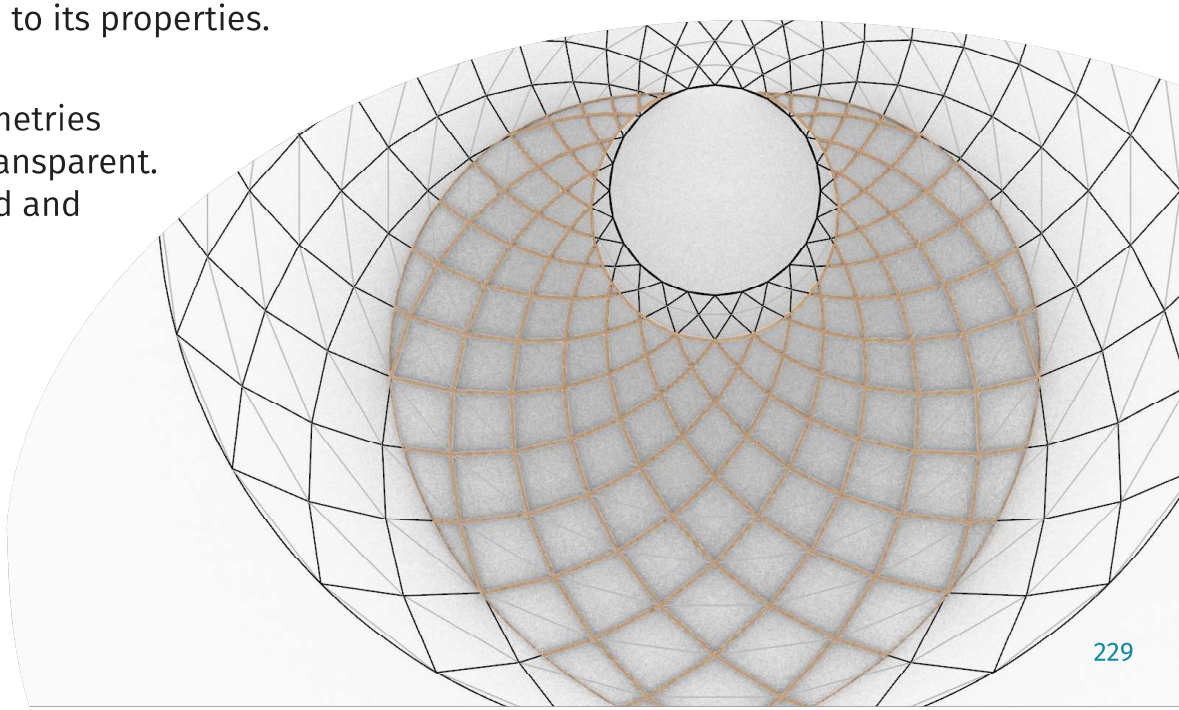
9.22 Powerful Principles

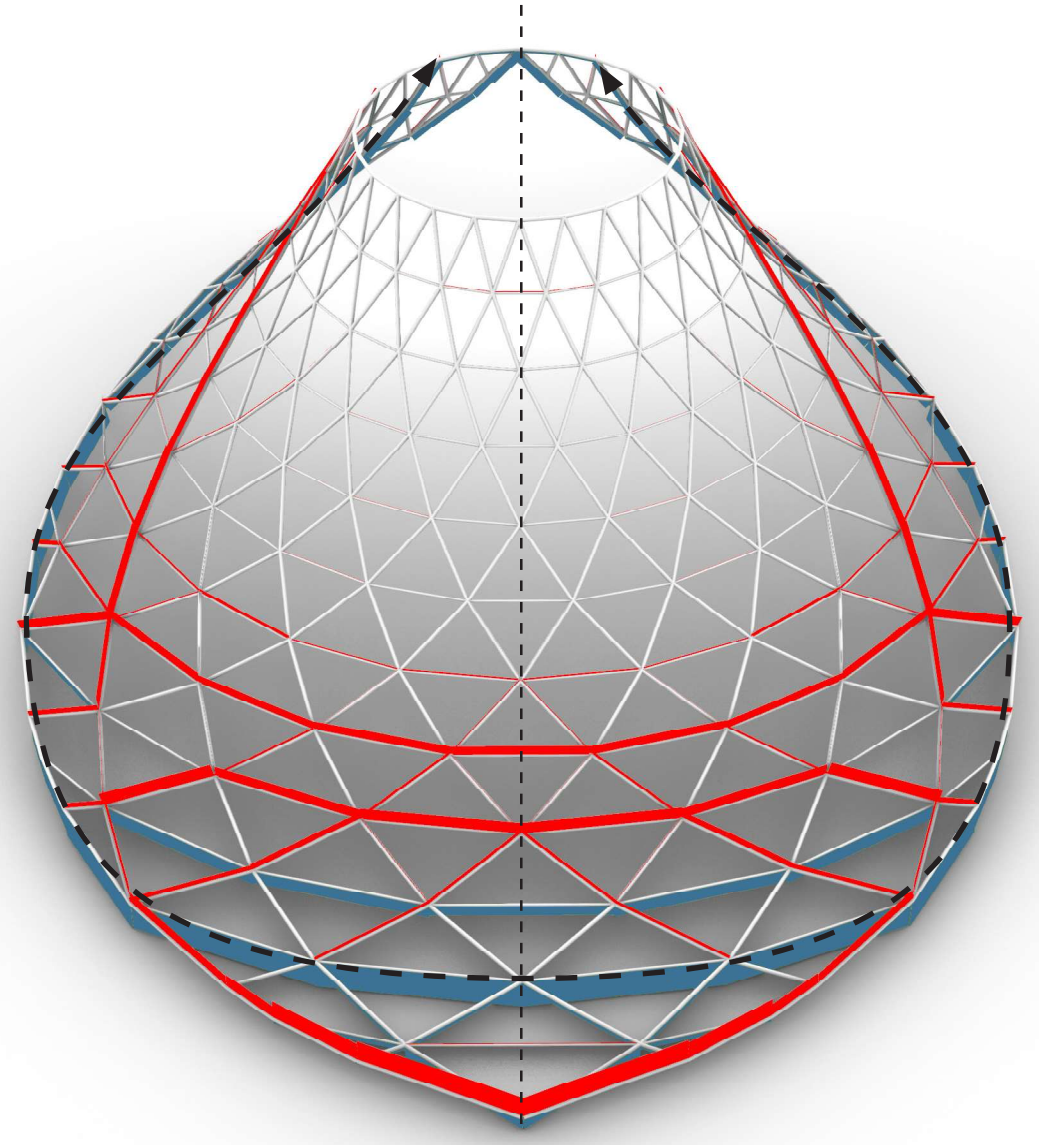
The structural principles of the Silesia Project are inspired by nature.

Fascinating strategies have evolved in the natural world to create effective and safe structures for shelter and protection. Moreover, these are often of inspirational efficiency and intrinsic beauty.

The Silesia Project abstracts natural principles into mathematics and later into building components. It looks at shell geometries as their curvature allows for minimal material use. It looks at timber as a renewable, sustainable material which exists in abundance in Silesia - and uses it in a way true to its properties. It combines these to create a unique timber grid-shell.

Grid-shells make use of the beneficial properties of shell geometries but their decomposition into struts make the surface highly transparent. It is also economical as material is concentrated where needed and market-ready as straight beam elements can be used.




Compression
Tension

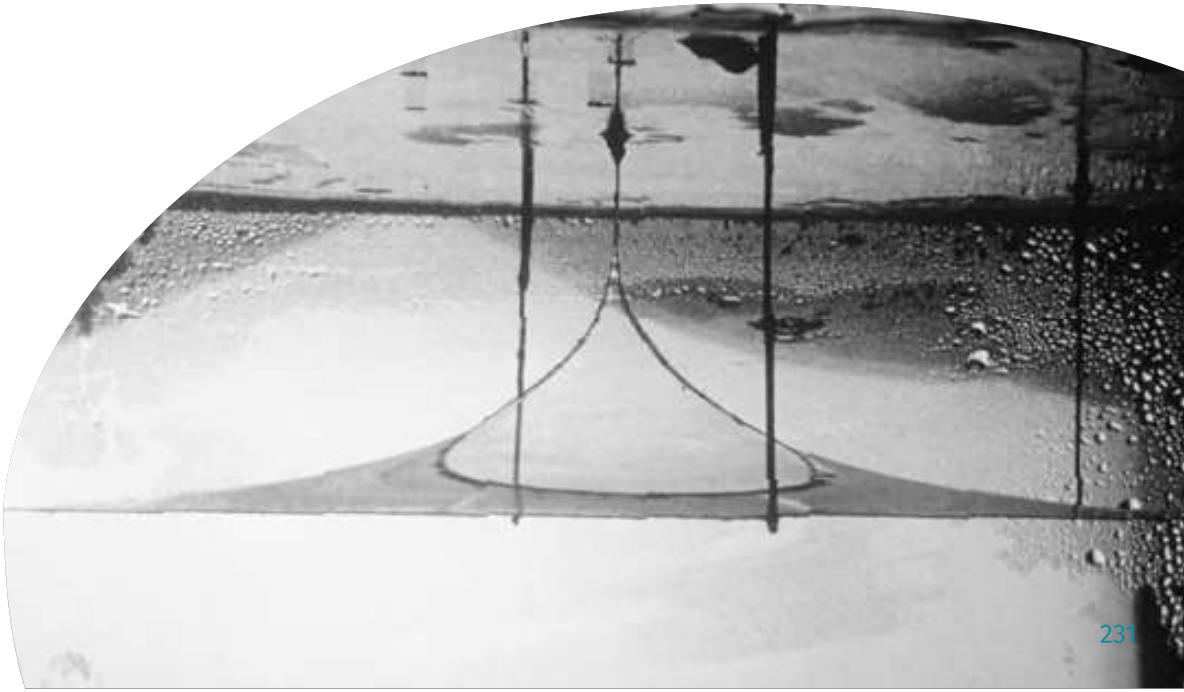
9.22 Powerful Principles

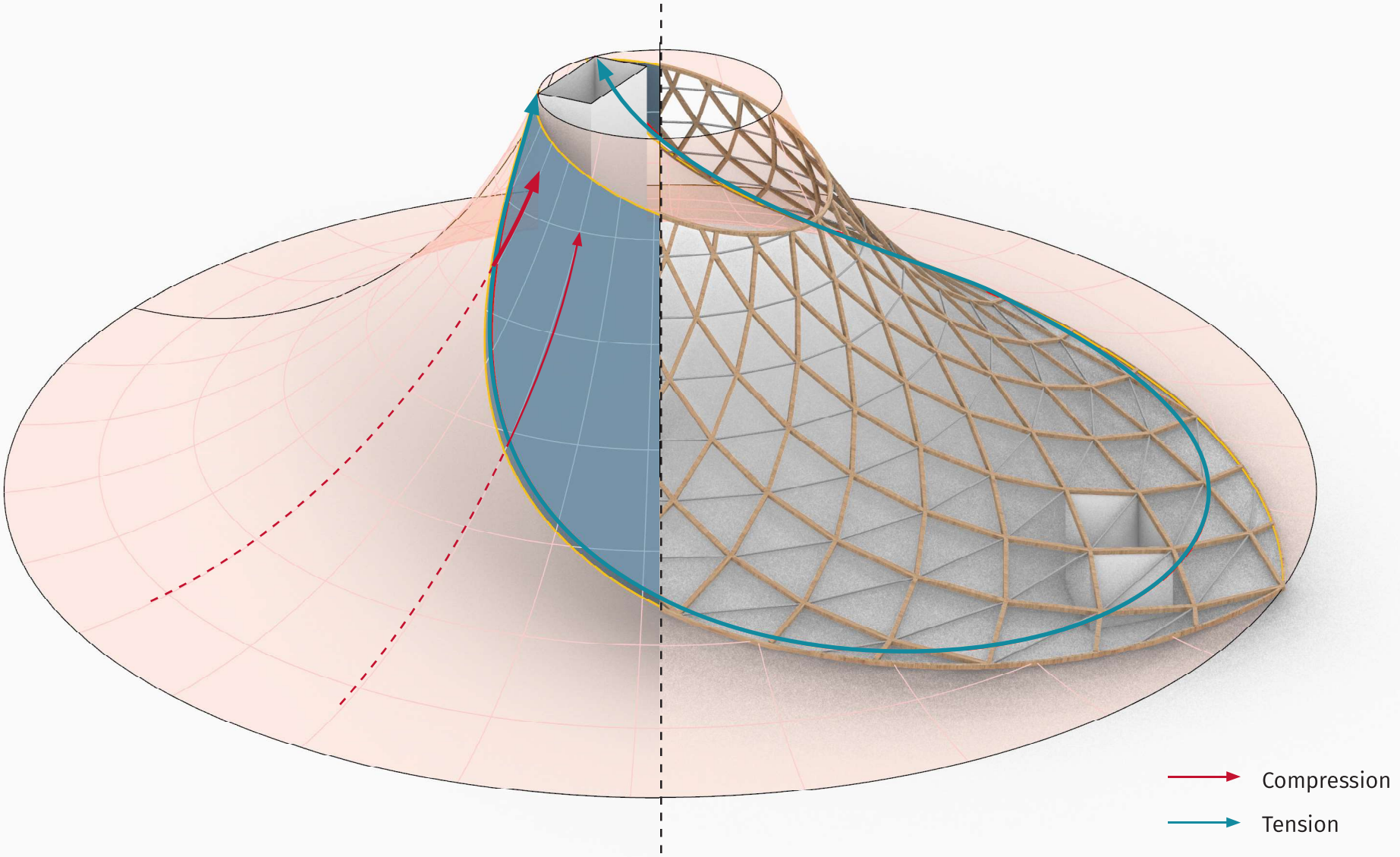
Natural Lightness

Suspended cables and their inversion, arches, are the most material efficient way of spanning large distances under load. While cables are in tension, arches are in compression only. It is thanks to their specific geometry that no bending exists in the structures. With their element loaded only axially, these structures can be very slender. Shell structures are the three-dimensional pendant to arches – and hence amongst the most efficient forms for covering large areas. Again, there is no bending; forces act in the surface of the envelope. The form of such funicular structures cannot be chosen freely but must be “found” depending on the load and support condition.

Classical arches or cable structures introduce horizontal thrust as well as vertical forces into the ground, requiring large foundations. By combining tension and compression systems, horizontal forces can be short-circuited, and the horizontal reactions eliminated, greatly reducing the required size of foundations.

The main grid-shell of the Silesia Project does exactly that. The horizontal thrust of a form-found compression-only shell is collected by a perimeter cable and introduced vertically into the central core. Under self-weight there are no horizontal reactions – and the roof envelope can be extremely slender.




Compression
Tension

9.23 An Integrated Design

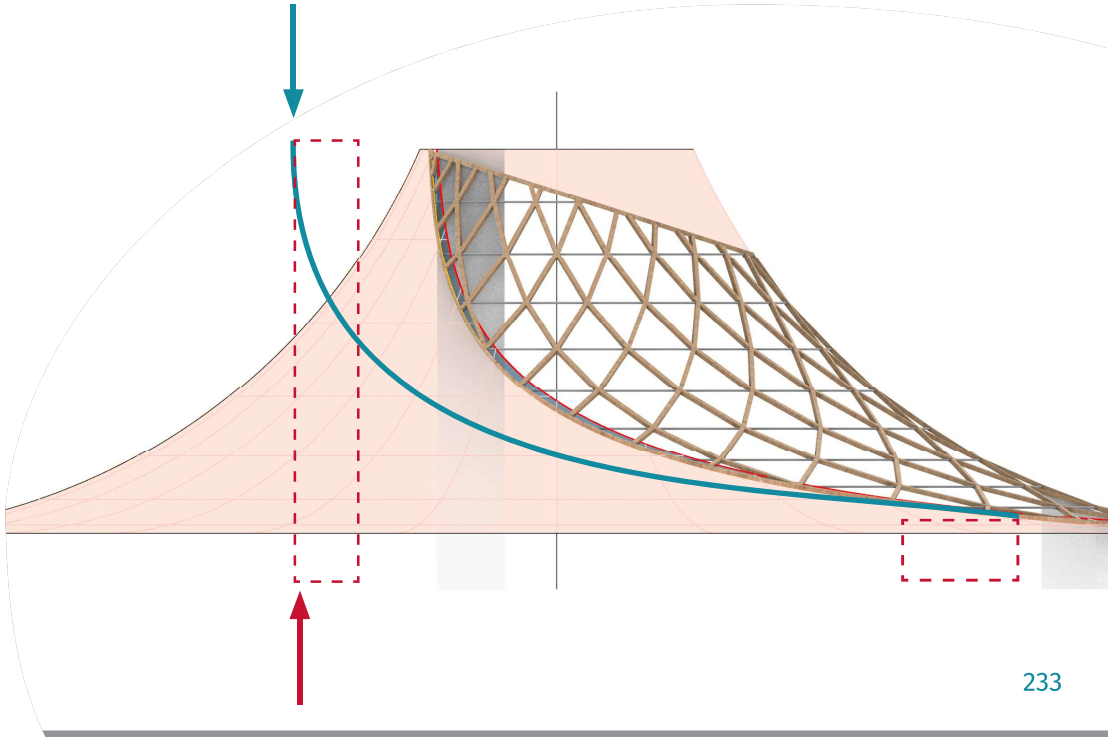
Envelope and core buildings – an integrated design.

The core buildings and roof act in concert to carry loads acting on the envelope into the ground. The cable which collects the tensile forces at the roof perimeter ends is anchored at the central core.

The cable tangent at the connection is nearly vertical, meaning the core is only loaded axially.

The material choice and geometry make the building extremely light weight. Internal forces are short circuited – under self-weight only vertical compression forces are introduced into the ground. The envelope's form is optimal to reduce the impact of wind forces, reducing horizontal reactions to a minimum.

These design decisions translate directly into the substructure, where foundations can be compact. Based on soil conditions, the use of recycled concrete or sustainable alternatives will be investigated.

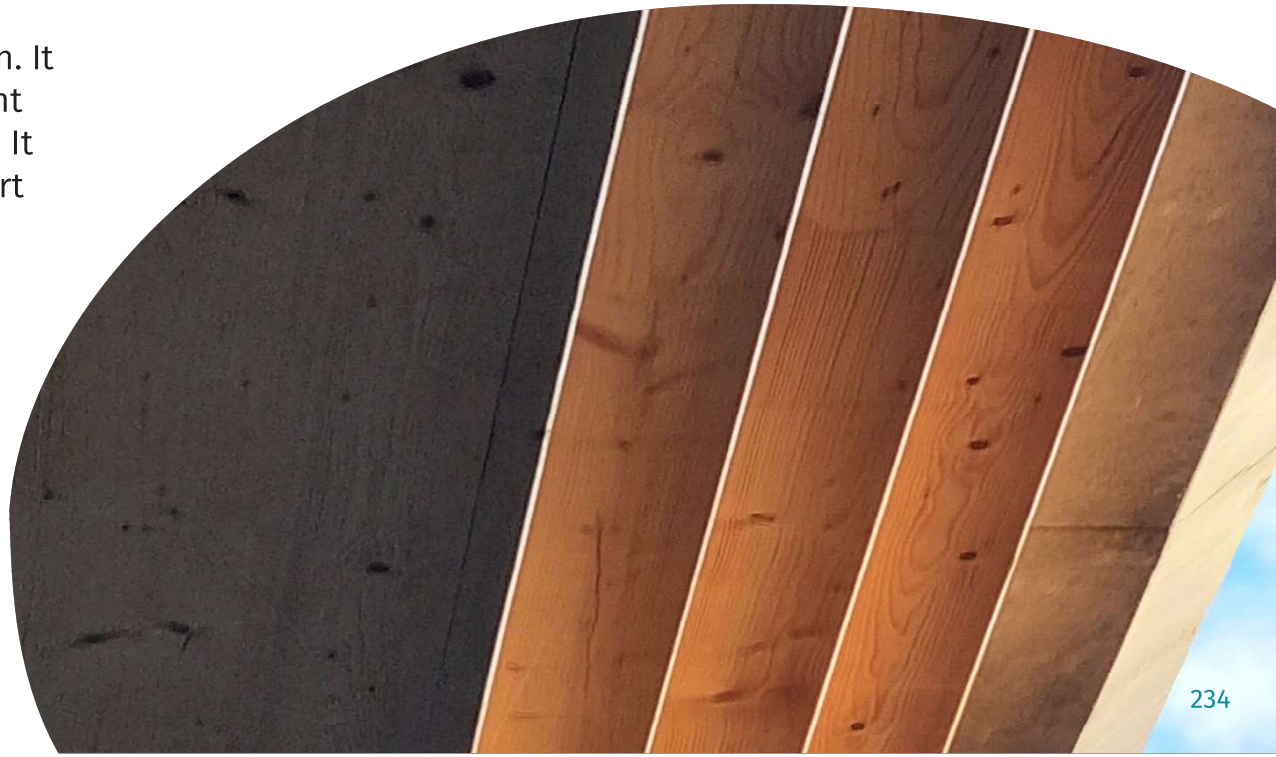


9.24 Timber

Timber should be sourced and processed locally and from sustainable forestry. Used in construction it actually serves as a carbon sink for the life-time of the building. The tectonic nature of timber makes component re-use easy when the building is decommissioned, extending its life-time and deferring the release of carbon far into the future.

Timber has fantastic material properties for construction. It has large compressive as well as tensile strength. Its light weight makes it an optimal choice for large span covers. It is good for the indoor climate and connoted with comfort and warmth.

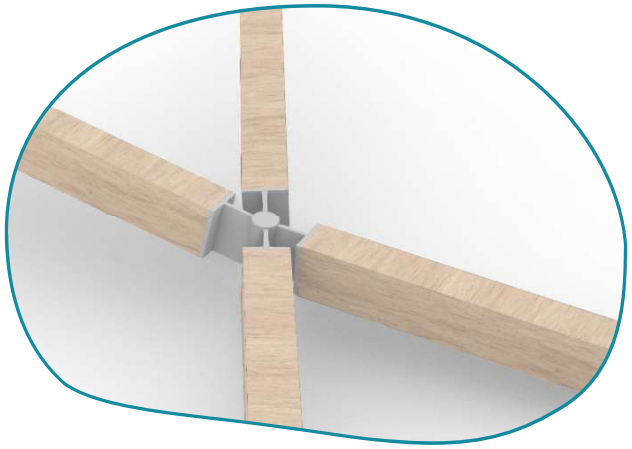
Carefully detailed, timber constructions are extremely durable.



9.24 Timber

Gridshell Elements

Grid-shells decompose the surface into beam elements and nodes. Together, they approximate the doubly curved surface. Various configurations have different advantages in terms of manufacture and aesthetic quality.

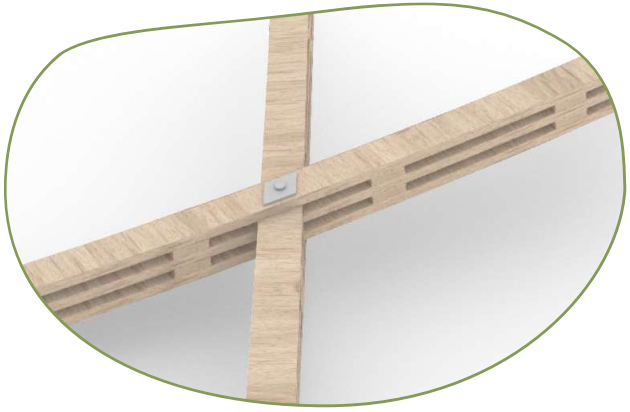


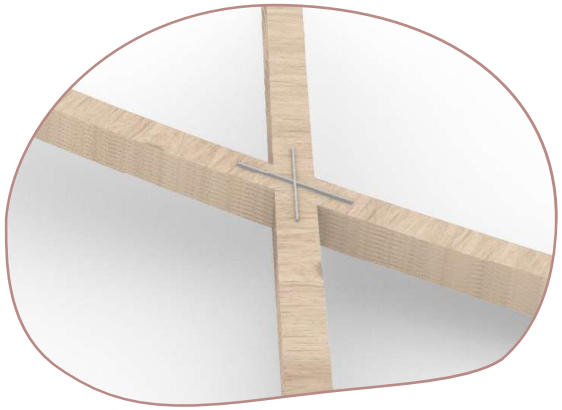
Standard sections

Straight rectangular timber beams. Welded steel geometry accounts for curvature.

Active bending

Slender laths are laid out flat on the ground. As they are lifted, they assume the desired shape. Steel pins push laths together.





3D-formed timber

Glued laminated elements are pre-formed 3-dimensionally. Simple steel connections.

9.25 Substructure

Mining Mitigation

The current development proposals and the nature of the site means that total risk avoidance is not a feasible option, although it is considered that the risks can be managed through effective site investigation and remediation. The coal mining risks will need to be managed throughout the design process through the application of suitably engineered design solutions. A site specific ground investigation should be undertaken in order to investigate, record and characterise the shallow and deep ground conditions across the site, including evidence of past coal mining / mine waste placement.

The 10t rule (where t = seam thickness) is often used to estimate the approximate worst-case zone of influence above mine workings, within which subsidence/settlement associated with void migration can theoretically occur if the workings collapse. As such, if the ground surface or base of foundations are within the 10t zone, remediation to stabilise the mine workings may be required. Current evidence suggests that even though the coal is below ~300 m bgl, this is already occurring in the area, so mitigation is likely to be required.

In terms of the building substructure, it is likely that mitigating the risk of differential settlement will be critical to future proofing the lifetime of the development. Feasible examples which could be used at the site comprise:

- Geotextiles - utilised to provide internal support to cuttings, embankments and other general landscaped areas.
- Grout - injected into the strata beneath the proposed building location to enhance and stabilise the layers at depth.
- Another option could be to surcharge the ground by using the existing spoil on site. By adding a large surcharge load to the proposed building location over a specified time period (6-12 months+), settlement is likely to occur. Monitoring of this process using horizontal inclinometers beneath the surcharge mound would be essential to provide data on the ground movements that occur and consequently inform future foundation design.

9.25 Substructure

Conventional shallow foundations such as pads or strip footings are unlikely to be feasible here due to the risk of differential settlement. It is likely that the following foundation solutions will be feasible subject to appropriate preparation of the ground and depending on the results of the site specific ground investigation (GI):

- Reinforced raft on reinforced earth. Reinforced earth will provide a stable base for the reinforced raft to sit on. The substructure is required to have a high strength to mitigate any below ground movements, hence the requirement for it to be reinforced with steel.
- Piled foundations – piled foundations are likely to be feasible as they transfer loads to more competent strata at depth (natural or grouted). See Figure 1 below.
- Piled raft – a combination of the above two bullets may be the most appropriate solution for this site.
- Vibro stone columns with reinforced raft are also an option – see Figure 2 below. Vibro stone columns provide ground improvement to the upper layers of the strata – this technique is more suited to granular material therefore is dependant on the results of the site specific GI. (More information can be found here https://www.keller.co.uk/expertise/techniques/vibro-stone-columns)

Figures 1 (piled foundations)

Figure 2 (vibro stone columns & raft)

Sustainability Considerations

9.26 Sustainability - Overview

The Eden Project aspires to create a foundation for humanity to live sustainably and equitably within the limits of the planet. This is core to the business and the projects we create.

To do this we need to shape the knowledge and decision making of people and culture to steward our direction of travel.

Eden Project's sustainability framework as a whole and on this project will do this in an evidence-based way.

It provides a compass that sets the direction of travel but not the final destination. That is not yet defined. Ultimately this will rely on Eden's artistry to create what is not yet known.

We wish to inspire and guide local, national and international policy in the belief we are improvable, and this will be evident in the Silesia Project.

As we take the next step in this journey In creating a sustainability framework for this project, we will review leading policies from around the world as well as regional ones and we will build on best practice projects from the region.

We will consider leading sustainability models such as the Five Capitals, planetary and social boundaries as well as the UN Sustainable Development Goals and regional initiatives.

We will work with our project partners to reflect long and hard on where we are now and where we want to be. Our outward and inward looking approach learns from and stands on the shoulders of the giants that precede us to give us the legitimacy to challenge the norm and raise the bar.

Science frames this debate. It is driving a sense of jeopardy as people realise that we are pushing the planet beyond its limits. Whilst some despair, we see opportunity to demonstrate that change is possible and this project can be at the forefront of this.

An emerging sustainability framework and the considerations that are seen in the design section of this report will be built on and provide a powerful means of transformation through setting aspirational objectives and a means to track our progress, learn and better ourselves.

It will allow us to be able to share our learning widely with others.

The projects sustainability framework will also be developed to recognise that sustainability is rich and context specific, reflecting the cultures of the communities in which we work.

Whilst we have translated these models to be meaningful to the Eden Project across its global projects, each project is unique and our approach to sustainability is designed to be flexible to respond to the locations and the communities in which we work.

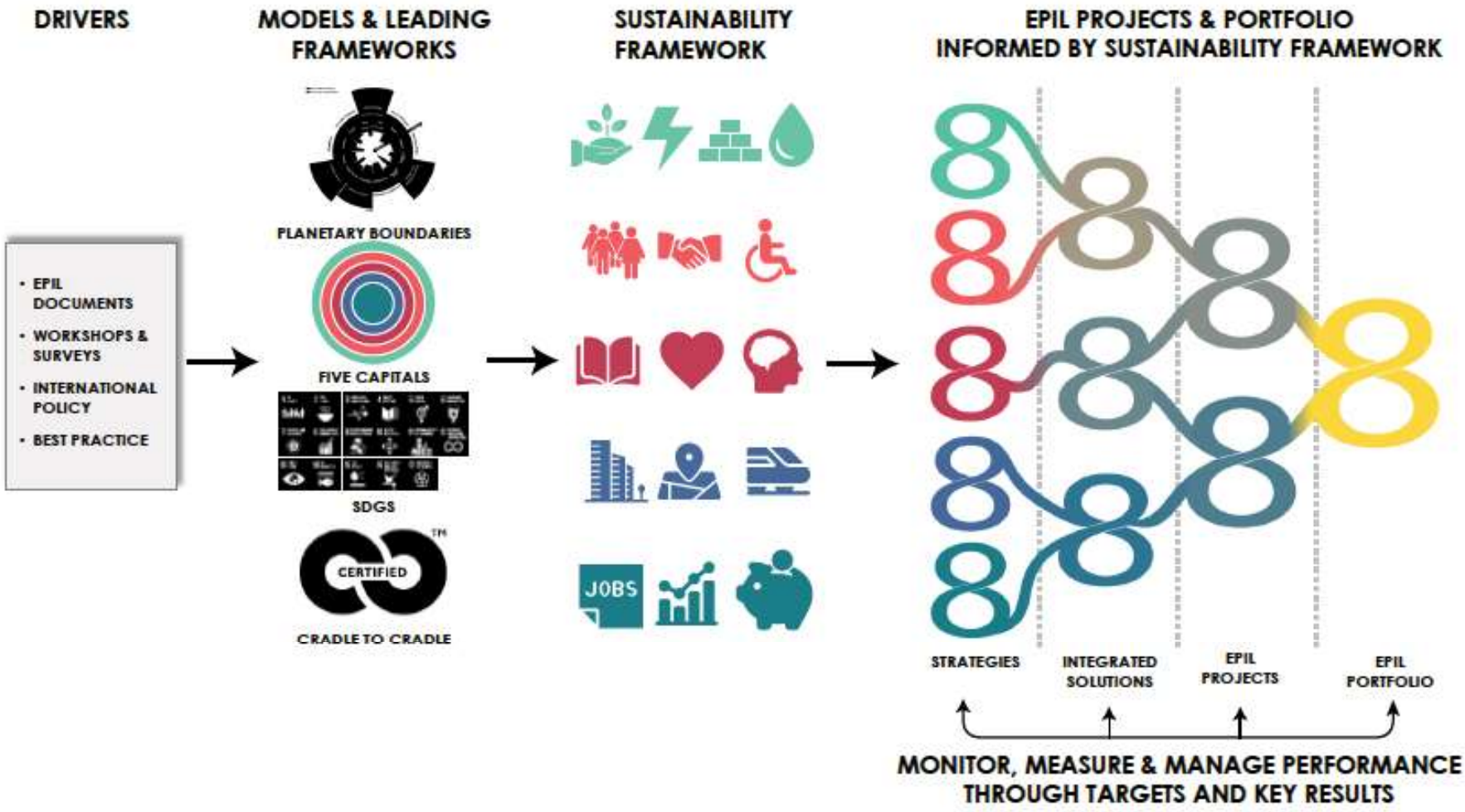
The adjacent image shows how a range of drivers will be considered. This places our sustainability framework not just in relationship with our overarching vision but also with international best practice.

It considers and pushes beyond leading international policy. We can be confident that it is holistic as it covers the Sustainable Development Goals, while responding to the planetary and social boundaries. It also encourages and endorses a cradle-to-cradle approach and considers throughout material health, material utilization, social fairness, water stewardship and renewable energy and carbon management.

We have chosen the Five Capitals as a strong sustainability model which emphasises our dependency on the planet and the importance of our social systems, knowledge and education. It also recognises the importance of the infrastructure, buildings and products that we create.

Finally, the sustainability framework considers financial capital. Here we go beyond traditional metrics which focus on money as a means to trade the other capitals. And instead advocates longer term mechanisms to deliver value for society.

9.27 Sustainability - Drivers



9.27 Sustainability - Five Capitals

Eden Project International has a Regenerative / Sustainability Framework through which all Eden Projects are informed. The key themes and objectives are structured around five aspects ('five capitals'): natural, social, human, manufactured, financial.

However, this framework is designed to be flexible; to allow a response to the location, cultures and communities within which each Eden Project works. As the design for the Silesia Project is developed, so too will Eden's Sustainability Framework evolve to best reflect the unique environment and culture of the region.