How the Eden Project Works

by Tom Harris

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Introduction to How the Eden Project Works

In March 2001, the Eden Project, a massive environmental center in Cornwall, England, opened to the general public. The finished structure is an unprecedented accomplishment -- a giant, multi-domed greenhouse, containing plants from around the globe. The site has already become a popular tourist destination, attracting thousands of visitors every day.

Special thanks to the Apex Photo Agency for the Eden Project photographs in this article!

Photo courtesy Apex Photo Agency, Photographer Simon Burt

The large, connected dome structures that house the Eden Project's many plants and exhibits

In this edition of **HowStuffWorks**, we'll see how (and why) Eden's creators undertook such an elaborate enterprise. We'll also explore the general concept of a greenhouse, as well as the particular structures used in Eden. Finally, we'll find out what the Eden team has in store for the future.

What is the Eden Project?

The Eden Project is a sprawling structure built along the side of a deep pit. The structure comprises three **biomes**, areas designed to represent three distinct climates found around the world.

The **Humid Tropics Biome**, the most impressive section, is a multi-domed greenhouse that recreates the natural environment of a tropical rainforest. The warm, humid enclosure houses

hundreds of trees and other plants from rainforests in South America, Africa, Asia and Australia. The dome is 787 feet (240 m) long, 180 ft (55 m) high and measures 360 ft (110 m) across at its widest point.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

An inside view of the Humid Tropics Biome, the centerpiece of the Eden Project

From the Humid Tropics Biome, visitors move on to the **Warm Temperate Biome**. The Warm Temperate Biome, which has the same multi-domed structure as the Humid Tropics Biome, houses plants from **temperate rainforests** around the world. Like tropical rainforests, temperate rainforests receive a high volume of rain every year, making them an ideal environment for varied plant life. But since they are farther away from the equator than tropical rainforests, they do experience distinct seasons (see How Rainforests Work for details). The Warm Temperate Biome at the Eden Project has varied plant life from temperate rainforests in Southern Africa, the Mediterranean and California.

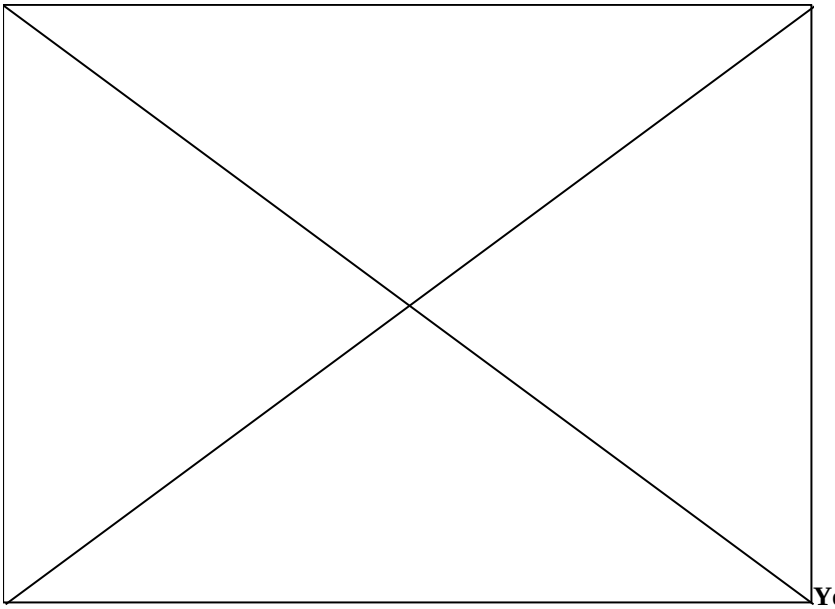
The final stop in the Eden Project is the **Roofless Biome**, an open area with varied plant life from the temperate Cornwall area, as well as similar climates in Chile, the Himalayas, Asia and Australia. Visitors can learn about plants that have played an important role in human history by following nature trails that wind over 30 acres (12 hectares) of land.

The creators of the Eden Project see the site as far more than a collection of greenhouses. Their mission statement is to "promote the understanding and responsible management of the vital relationship between plants, people and resources, leading towards a sustainable future for all." To this end, they have included informational kiosks and artistic installations throughout the biomes. They also hold a number of workshops and special events, all designed to inform people about environmental issues. To learn more about the Eden Project's mission, as well as its upcoming activities, check out the Eden Project Web site.

From a technical viewpoint, the most amazing thing about the Eden Project is its giant greenhouses. In the next few sections, we'll find out how these monumental structures work and how they were built.

Greenhouse Basics

To understand how the Eden Project's super greenhouses work, you first have to understand the fundamental concept of a **greenhouse**. The most basic greenhouse would be a simple box made out of solid, transparent material, such as glass or clear plastic. When sunlight shines through the transparent walls of the greenhouse, it heats the material inside. Let's consider how this works in a greenhouse with a dirt-covered floor.



Your browser does not support JavaScript or it is disabled.
Click on the button to see how a greenhouse heats up.

Radiation energy from sunlight heats up the greenhouse floor. The floor releases some of this thermal energy, which heats the layer of air at the bottom of the greenhouse. Warmer air is lighter than cooler air (that is, it has a lower density), so the heated air rises to the top of the greenhouse. When the heated air rises, cooler air replaces it at the bottom of the greenhouse. This air becomes heated by the floor and also begins to rise.

This process is going on in our atmosphere all the time. When the sun shines on an area, it heats the ground, which heats the air above it. The heated air rises through the atmosphere, cooling down as it moves upward. This is why air near the ground is warmer than air higher up -- the air near the ground hasn't had as much time to cool.

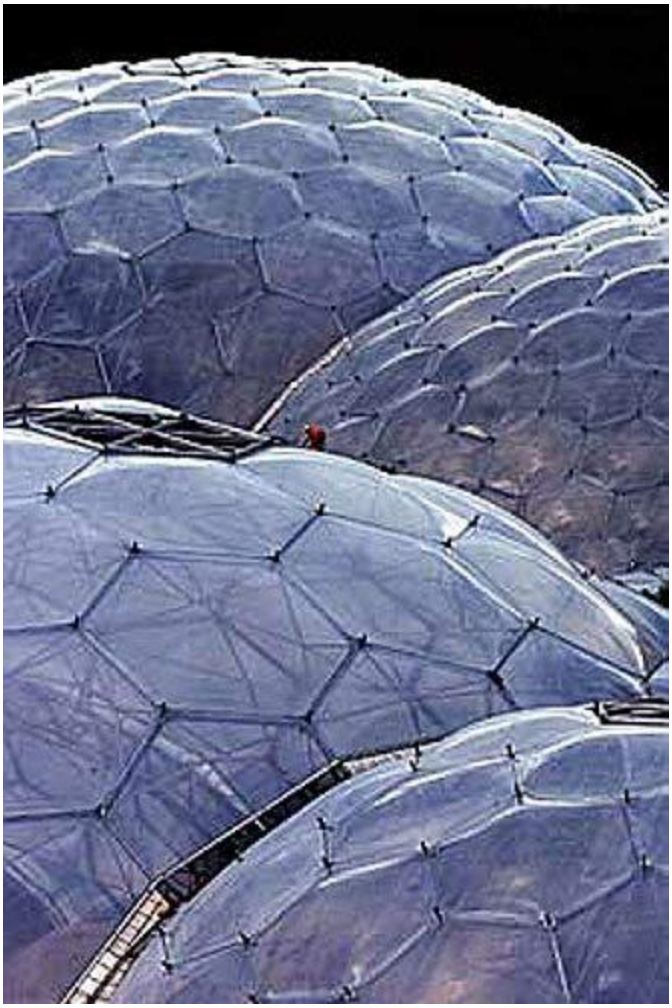


Photo courtesy Apex Photo Agency, Photographer Simon Burt

The giant dome structure of Eden's greenhouse roof dwarfs a worker installing the transparent panels.

Then what makes the air in a greenhouse hotter than the atmosphere outside? Simply put, there is a smaller quantity of air that needs to be heated inside a greenhouse. In the Earth's atmosphere, there is a mass of air that extends more than a mile (1.6 km) above the ground (at most points). Even giant greenhouses like the ones in the Eden Project contain only a tiny fraction of this air mass. The greenhouse floor can heat its smaller volume of air much more efficiently than the ground outside can heat all of the air contained in the Earth's atmosphere.

The heated air in a greenhouse rises to the ceiling, is replaced by even warmer air and gradually sinks back to the floor. The circulation path is short enough that the sinking air is still relatively warm when it reaches the floor, and so can be heated to an even higher temperature than before. The ground and air absorb enough heat during the day to keep the greenhouse relatively warm all night.

This is the basic idea behind any greenhouse, no matter its size. Most greenhouses function as a controllable environment for plant life. The plants get all the sunlight they need to survive, but they are not fully exposed to the natural elements.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

Workers finishing Eden's largest dome, in June 2000

You can't really control air temperature with a simple glass box, because the amount of sunlight varies a good deal from day to day. To maintain the same optimal conditions year-round, a greenhouse needs additional climate-control features. A typical greenhouse will have some sort of venting system, so air can be released when the temperature rises too high, and some sort of heating system, so the air can be warmed when there isn't enough sunlight. Additionally, a greenhouse needs a plumbing system to keep the ground and the air moist.

As you can see, there are a number of elements that go into constructing a greenhouse. In the next few sections, we'll see how the people who built the Eden Project dealt with these issues.

The Domes

In the last section, we looked at the most basic greenhouse, a simple box made of transparent glass or plastic. Eden's designers decided not to use these traditional materials in their greenhouses -- they went with glazed **ethyl tetra fluoro ethylene (ETFE) foil** instead. ETFE foil is a perfect covering for a greenhouse because it is strong, transparent and lightweight. A piece of ETFE weighs less than 1 percent of a piece of glass with the same volume. It is also a better insulator than glass, and it is much more resistant to the weathering effects of sunlight.

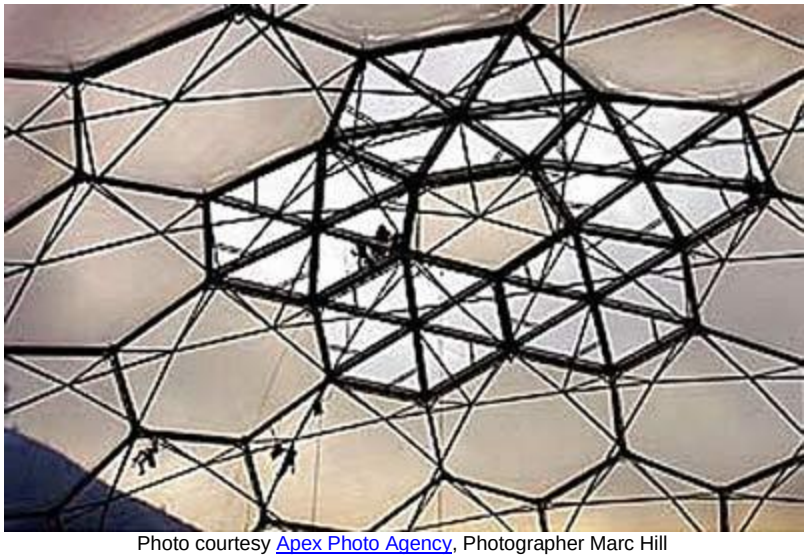


Photo courtesy Apex Photo Agency, Photographer Marc Hill

Workers installing ETFE foil panels in the dome ceiling

The Eden Project designers formed this ETFE material into extremely sturdy **pillows**, each made from three sheets of ETFE foil welded together along the sides, one on top of the other, with layers of air pumped in between them. The air layers provide increased insulation without decreasing the amount of sunlight that shines through. The coolest thing about these pillows is that they are adjustable: On a colder day, they can be pumped up with more air to provide better insulation; on a hotter day, they can be partially deflated to allow more cooling.

Eden's designers attached pillows together to form **geodesic domes**. In this sort of structure, many flat panels, formed into triangles, pentagons, hexagons or other polygons, are pieced together to form a curved surface. This design is remarkable because none of the individual pieces are curved at all, but they come together to form a rounded structure.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

Each ETFE pillow is secured in the steel framework.

In the Eden Project domes, these geometric panels are the ETFE pillows. Each pillow is attached to a web of interlocking steel tubes. Each dome actually has two web layers, one with hexagonal and pentagonal panels and one with triangular panels. The total Eden structure uses 625 hexagons, 16 pentagons and 190 triangles.

Like the steel grid in a skyscraper, the steel frame of the geodesic dome is incredibly strong relative to its weight. This weight (667 tons) is dispersed evenly throughout the entire structure so that the dome only needs support around its base, leaving lots of room for the plants inside. The edges of the dome rest on a sturdy **foundation necklace**, an underground concrete wall around the perimeter of the structure.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

Workers assemble the steel framework of the greenhouses. The Eden Project crew broke the world record for largest free-standing scaffold.

Designing these sorts of domes is a mind-boggling exercise in geometry. You have to figure out exactly which shapes to use and how to fit them all together to form a perfectly curved structure. Eden's designers figured everything out using sophisticated computer software. The software generated precise 3-D computer models of the different domes, which the designers fed into an automated **production-line computer**. Using the 3-D models, this computer determined which pieces the construction crew would need and directed machines to cut steel beams to those exact specifications. When it came time to build the domes, the crew simply followed the instructions and put all of the pieces together.

One advantage of the geodesic dome shape is that it adapts easily to most ground surfaces. Eden's designers describe the domes as giant bubbles that can be set down just about anywhere. The designers built the domes along the side of the pit that faces south, since the Sun is in the southern part of the sky in Cornwall (click here to find out why). The slanted ground is perfectly positioned to absorb thermal energy all day long, heating the air even after the sun has gone down.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

Putting all the pieces of the dome together, in April 2000

Capturing light is only one part of maintaining a greenhouse, of course. For the plants to thrive, you also need to provide good soil and adequate water. In the next section, we'll see how this is done in the Eden Project biomes.

Plumbing and Climate Control

The site chosen for the Eden Project is ideal in many ways -- it receives plenty of sunlight, has a south-facing slope and is relatively accessible -- but in the beginning, it did have a few problems. One of the first obstacles was the ground material. The pit was composed mostly of clay, which does not have the necessary nutrients to support extensive plant life. Before the crew could begin constructing the greenhouses, they had to build up a level of nutrient-rich soil.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

The site of the Eden Project, before construction began

They produced this richer soil by mixing **clay waste** from the area with **composted green waste**. Composting breaks waste material down to produce a nutrient-rich fertilizer. By combining this

fertilizing material with the available dirt, the Eden crew was able to build a rich soil that would have taken hundreds of years to develop through normal geologic processes. In all, the crew produced some 85,000 tons of revitalized soil, more than enough to support the biomes' varied plant life. (See How Composting Works to learn more about the biochemical processes involved.)

In the early days of construction, the Eden Project was hit with another major obstacle: flooding. After two months of heavy rain, some 43-million gallons (nearly 163-million L) of water had drained into the bottom of the pit. In order to build a solid base for the structure, the designers had to find a way to channel the water so it wouldn't erode the ground below. And as long as they were channeling the water, the designers figured, they might as well put it to work.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

The domes were built along the north side of the pit, so they would get maximum sunlight from the south.

The first step was to build a **sump**, a water-collecting pool under the rich soil. Then they laid a buried layer of matting to channel rain water and any runoff water into this sump. The mat also filtered out most sediments, generating a constant source of clean, filtered water. This water is pumped out of the sump up into Eden's structure, where it is used to irrigate the plants, as well as drive the building's plumbing. This system collects, on average, almost 6 gallons (22.71 L) of water every second -- about 20,000 bathtubs of water every day. The greenhouse ceilings also collect rainwater, sending it to the sprinklers that keep the air saturated.

With the plants, domes, soil and plumbing all in place, Eden is now a fully functioning greenhouse. But its creators still consider it a work in progress. In the next section, we'll find out about some of the additions that are in the works and about the long-term goals of the Eden team.

Long-term Goals

The main goal of the Eden Project is to educate the public about the natural world. Specifically, Eden's creators want to expose visitors to the issue of **sustainable development** -- using natural

resources conscientiously so they will continue to be available for human use in the future. The facility is intended to be an entertaining attraction to tourists, but the Eden team also wants to further environmental research and education.

Photo courtesy Apex Photo Agency, Photographer Nick Gregory

An aerial view of the finished structure

To this end, the Eden Project will open its doors to a wide variety of companies and organizations interested in sustainable development, ecological science and many related areas of study. As the project evolves, its creators hope the site will become a meeting place for anybody interested in these issues. The idea is to bring researchers, writers, students and others together to advance the progress of science and society.

The Eden team is already developing many new programs for younger students. Some exhibits will incorporate elements from popular children's books, such as the "Harry Potter" series and classics by Roald Dahl, in order to give kids a comfortable way of accessing the world of science. The Eden educational division is also setting up a program that would link schools from around the world. In this way, kids could learn about the natural environments in other parts of the world, as well as the cultures that interact with them.

Photo courtesy Apex Photo Agency, Photographer Simon Burt

One of the tropical butterflies released into the Humid Tropics Biome

The Eden team will also keep working on the greenhouses themselves, of course. New plants are added all the time, and in spring 2001, butterfly expert Christopher Wood began introducing exotic butterfly species to the enclosed biomes. To avoid a population boom that could disturb the plants, the plan is to introduce only male butterflies. If the butterfly project goes well, the Eden team may introduce other animal species in the future.

At this point, Eden's creators have left everything wide open -- they want Eden to evolve naturally. The building is even designed so that it can change over time. The ETFE pillows are built to detach easily from the steel frame, so they can be replaced should a more efficient material come along. If the Eden Project is a success, it will continue to expand and develop in the decades to come.