**Narrative**

**eTREE, an Homage to Nature:**

Nature has already perfected the art of sustainable energy generation in the form of trees. Beautiful not only in aesthetics but also function, trees generate the energy that they need to survive while providing other forms of life with oxygen, shade, and nutrients.

The eTREE emulates this positive cycle of generation by harnessing the powers of the sun and the wind to generate clean energy. Contrary to the monumental form and scale often associated with land art, eTREE takes on the form and scale of the trees that we encounter and interact with in our everyday lives.

**Learning from the Tree: Innovative Technology in Sustainable Production and Energy Generation**

The membrane of the eTREE, representing thee leaves of the tree is manufactured by 3d printing with recycled wood cellulose filament. This material is not only lightweight but also durable and can withstand a large amount of tensile stress. 3d printing provides the material with the freedom to customize the shape, size, etc. As leaves on a tree produce energy through photosynthesis, the e-tree produces solar energy through solar cells that are scattered along the membrane. The distribution of these panels is optimized by the sun paths of the installation area.

The frame of the eTREE, representing the branches of the tree, which hold the membrane up is made from GRP(Glass fiber Reinforced Plastic). The frame of the e-tree is pre-tensioned to withstand sagging due to gravity and to counter lateral wind loads. The GRP(Glass fiber Reinforced Plastic) and the membrane counteract each other’s forces in a sturdy equilibrium, just like in a popup tent.

The central supporting column of the eTREE represents the stem of the tree. Made from the same GRP material, the stem supports the membrane and the frame, which oscillate up and down like a spring in the wind. Generators are distributed along the stem of the eTREE to convert the kinetic energy of this oscillation into electricity. Contrary to traditional wind turbines, the spiral shape of the eTREE has no given directionality, allowing it to harness wind from all directions.

The cells buried in the ground of the eTREE represent the roots of the tree. As some plants like potatoes store nutrients in their roots, the eTREE stores the generated energy in those cells. This stored energy is used to power electric bicycles and other electronic devices of those using the park. The rest of the energy is used at BUGA and sent to the power grid of the city of Mannheim.

The lightweight, modular nature of the eTREE allows it to be assembled, disassembled, and moved with ease. The typical eTREE designed for Mannheim with a total of 6 revolutions in the spiral has a total height of 15 meters and a maximum diameter of 14 meters. Thus, the bounding box volume is a total of 3,430 m3. The main structural GRP stem has a diameter of 150 to 175.5 millimeters which are disassembled into 7 pieces, each with a height of 2.5 meters. Thus, the bounding box volume of the disassembled tree is 2.14m3. The 2 GRP frames that support the membrane each have a diameter of 30 millimeters and a total length of 71m which can fit into a bounding box volume of 164.64m3 when disassembled.

 The flexibility of the eTREE system allows it to adapt to its environment and to the diverse needs of the owners. Due to this versatility, the eTREE can be installed anywhere, optimized to each context. This new typology of art generator will not be confined to parks but will penetrate deeply into urban settings, lining streets and filling backyards.

**High-tech but low profile**

Mannheim’s Spinelli park will be the site for the BUGA 2023 expo. In contrast with the colorful expo grounds, where flora from all over the world will be displayed to the public, the rest of the park remains a barren and empty field, with a military past. This grey and unused land are set to transform into a park with bicycle lanes and hiking trails binding the park and the surrounding urban fabric into one.

The eTREEs will be linearly scattered across the park, alongside natural trees. Carefully distributed with respect to the green corridor, the linear placement will be focused on the main nodes of the trails and paths. As the e-trees visually overlap with each other and with other trees, the experience of those passing through these trails will be like passing through a dense forest.

Visitors can use the power outlets stemming from the eTREEs to charge their electric bicycles and their electric devices. Sensors will gather data on energy consumption and the weather and will display this information to the public through interactive LED lighting. A large bulk of the energy will be diverted to BUGA 2023 to meet the power needs of the expo. The eTREE will be installed all over Mannheim, not just in Spinelli park, powering households and urban farms, etc.

The activities associated with the ETREE can be listed as the following:

* Electric vehicle charging
* Electric device charging
* Data-driven, interactive LED lighting
* Solar, wind analysis and data gathering through sensors
* Energy consumption data gathering
* Powering automated urban farms
* Energy storage and transfer

**Harnessing the Powers of the Wind and Sun: Powering the city of Mannheim**

**Energy output:**

Average radiation of Spinelli park = 1100kwh

Total output of all the solar panels per eTREE = 31.47kWh (12% efficiency)

Average windspeed of Spinelli park = 3.08m/s

Total output of all the wind generators per eTREE = 0.264kWh (30% efficiency).

This method of generation is like the Savonius vertical generator, in which the amount of generated energy is proportionate to the area of the surface affected by the wind.

Total Area of the unrolled membrane of the eTREE = A

Air Density Coefficient =  0.5\*1.225kg/m^3

Energy Pattern Coefficient = 1.92

Area(A)/2 x air density coefficient (0.5\*1.225kg/m^3) x energy pattern coefficient (1.92) x windspeed^3(m/s)/1000 = 1.144 kWh

Operating at 30% efficiency, a total of 0.264 kWh is generated through the wind.

Adding the total generated electricity through both solar and wind, the amount of energy generated annually by one eTREE = 31.47 x 365 + 0.264 x 24 x 365   = 13.799 MW.

Since there are 155 eTREEs in the park, the total output = 155 x 13.799 MW = 2138.845 MW

**Clean Energy, Low Maintenance, Zero Impact**

The eTREE generates clean and efficient energy with no harmful byproduct. The membrane and the structure are all made from recycled materials which can be used again or biodegraded. The ETREE has a minimum impact on the environment from its production to its disassembly.

Once the eTREE is installed, the system requires no further maintenance and can function independently. Because all the eTREEs are linked to a real-time central database, any malfunctions can be tracked down remotely by observing erratic outliers in the data. Affordability in maintenance is a key factor in the system, adding to the versatility and universality of the eTREE.

**Cost Estimate:**

Cost estimate will be made for one eTREE in Mannheim (6 revolutions, total height of 15m, total diameter of 14m). GRP

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Component | Material | Quantity needed | Cost per unit | Total Cost | Equation |
| Solar panels | Photovoltaic cells | 31.47kWh | US$ 0.9 /Wh | US$ 28,323 | 31470Wh x $ 0.9 /Wh = US$ 28,323 |
| Frame | Glass fiber reinforced Plastic | Φ60 142 m x 1.2(loss) | US$ 4.00 / m | $ 681.6 | 142 m x  1.2 x $4.00/m = US$ 681.6 |
| Stem | Glass fiber reinforced Plastic | Φ175 17.5 m x 1.2(loss) | US$ 30/m | US$ 630 | 17.5 m x 1.2 x $$ 30/m = US$ 630 |
| Membrane | vinyl encapsulated cellulose mesh membrane | 312.47 x 1.2 m2 (loss)  = 374.96m2 | US$ 0.55/m2 | US$ 206.23 | 374.96m2 x $ 0.55/m2 = US$ 206.23 |
| Energy harvesting Generator | - | 5 units | US$ 24/unit | US$ 120.00 | 5 x $ 24 = US$120.00 |
| Total cost: $ US 29,960.83 | | | | | |

**Prototype development:**

Mannheim is famous for the achievements it has made in the field of Engineering. The 3D printed membrane will thus utilize the 3D printing equipment at the Mannheim University of Applied Sciences. The GRP will be molded and cured at the fabrication lab. The materials used in the manufacturing process are made from recycled materials which can be sourced with little effort. The scale of the working prototype will be ¼ of the actual product, for ease of production and assembly.

**Environmental Impact Summary**

Nature has already perfected the art of sustainable energy generation in the form of trees. Beautiful not only in aesthetics but also function, trees generate the energy that they need to survive while providing other forms of life with oxygen, shade, and nutrients. The eTREE emulates this positive cycle of generation by harnessing the powers of the sun and the wind to generate clean energy.

The eTREE is designed with a flexible, modular, and highly optimized system. This system can easily be accessed and utilized through a one-stop app, which allows users to analyze the solar and wind data of the installation site and optimize their tree according to this data and their personal needs. This system of optimization is devised to cut down on waste material and extra carbon emissions due to over-specification.

The membrane of the eTREE is 3d printed with a recycled wood cellulose filament. This innovative material is recycled from the leftovers of wood production, with minimal embodied carbon. The material itself can be recycled as filament or can be biodegraded with minimal impact on the environment. Natural trees, provide oxygen, shade, and nutrients to other lifeforms during their lives and even at the end of their lifecycle, pass on nutrients to the soil. It is this fully sustainable cycle that we strive to emulate in our design.

The main structural members are manufactured from lightweight glass fiber reinforced plastic. The plastic particles that bind with glass fiber to produce this material are shredded from plastic waste. This modular system of GRP members can be disassembled and assembled with ease. The entirety of the eTREE can thus fit in a small and light package, minimizing the carbon footprint of delivery.

eTREE takes on the form and scale of the trees that we encounter and interact with in our everyday lives. Unlike conventional forms of monumental land art, which can potentially harm the ecosystems of the site, the eTREE app uses big data to assess migratory routes and natural habitats of each site, to minimize this impact. The shape and the scale of the eTREE are far from monumental, allowing the eTREE to blend in with the natural trees of the area. The eTREE was not designed to stand out, but to harmonize with its natural surroundings.

Due to this versatility and neutrality, the e-tree can be installed anywhere, optimized to each context. Installing it in various locations will allow the central database to gather useful data about energy consumption and generation which can be used to further hone the optimization process. This new typology of art generator will not be confined to parks but will penetrate deeply into urban settings, lining streets, plazas, and filling backyards.