**1,500-word narrative**

**Productive Frictions: E3 (Energy/Ecology/Economy)**

Conflicts and frictions can be destructive. However, friction can also be converted into productive kinetic or thermal energy. Further, it can be stored for later use. **Productive Frictions: E3 project produces energy, ecology, and economy** that becomes a socio-economic infrastructure for its context. One of the main aims of this project is to explore how energy-producing infrastructure can be integrated into park designs and daily leisure activities. This project examines how the E3 proposal can become a site-specific design and how flexible it can be to be replicated elsewhere, triggering more open, productive, and sustainable public spaces.

The project engages historical context by engaging Mannheim's existing grounds and the urban context. First, the site's historical Spinelli Barracks building footprints are overlaid on the overall park, which eventually generates the park's pedestrian paths. These lines are then superimposed onto Mannheim's human-scaled walkable historical Quadratestadt grid (about 65 m x 200 m), providing a park with pedestrian-friendly infrastructure.

These layers and lines are combined with a tertiary 20-meter square grid that informs the locations of the E3 Poles. 20-meter-tall poles are first placed at all of the intersections of the grid, then later removed according to the needs of the specific location's condition. A total of 838 poles of various types cover the entire site; they produce energy, ecology, economy, and sequester carbon. The 2-meter-tall modules within the E3 poles are stacked and interchanged to adapt to the nature of the public space it is located.

The first "A. Standard" type E3 pole includes a carbon sequestration module at the base, which can sequester up to 5.5 tons of CO2/year. The two bird habitat modules, four solar panel modules, and three different wind turbine generators are stacked on top of this base. This pole type has an anticipated annual capacity of 915 kWh. The numbers are based on Mannheim's average wind speed of 3.8/ms, average Global Horizontal Irradiance (GHI) of 3.1, and yearly total solar energy potential of 1,131 kWh/m2.

The second "B. Bird habitat" E3 pole type includes the same carbon sequestration base module at the bottom, and five bird modules, three solar modules, and one wind module stacked on top. The bird habitat provides small spaces for various birds and other species to engage with the E3 poles. These pole types are primarily located in green vegetive areas within the newly planted trees that are intended to capture carbon as they grow over the next 20 years. The Live Oak tree, London Plane tree, and Chestnut tree were selected for their effectiveness in sequestering carbon. As an overall system, the pole can produce up to 720 kWh annually.

The third "C. Wind" E3 pole has five "Mechanical Trees" stacked at the bottom half, sequestering up to 27.5 tons of CO2/year. In addition, five wind turbine modules of three different types are stacked at the top half taking advantage of the flowing wind at the higher level above the ground. This combination of modules has an anticipated annual capacity of 635 kWh and is intended to be placed in publicly active places.

Lastly, ten two-meter solar panel-clad cylinder modules producing 1,350 kWh per year make up the fourth "D. Solar" E3 pole.

A total of 838 poles comprising different types of pole combinations mentioned above can produce up to 7,028 MWh annually.

In addition, to the E3 poles, 31 large solar panels are spread across the site generating about 350 MWh of electricity yearly. These large solar panels are connected and interact with the E3 poles. The solar panels generate electricity, provide shade, and add visual interest to leisurely activity. The panels are placed in active public areas, such as the running tracks, skate parks, BMX paths, and water pool areas within the park. They illustrate the possibilities of combining energy production into our daily outdoor spaces.

These combined on-site technologies would generate about 7,400 MWh of energy annually. In addition to this energy production, surfaces of crowded pedestrian pathways, main bike paths, running tracks, BMX paths, and skate parks will integrate pressure-based piezoelectric technology to generate additional energy.

Further, green waste from community gardens, tree nurseries, and animal waste from the animal therapy areas feed the two underground biodigesters (2x250m3) that generate energy from biogas. This clean, renewable, and reliable baseload power (about 20 cows equivalent, producing 1,168 MWh of power a year) complements the E3 power generation, which can be supplied to neighboring housing units or stored on site.

Potential excess energy production can be stored on site using the Closed Pumped Storage Hydropower (PSH) technology. The higher and lower water reservoirs of the PSH system also perform as a leisurely space for activities such as kayaking.

**The annual capacity of the overall park would be around 8,500 MWh +. This amount can power about 343 households that consume 25kWh per day.**

One of the other major features of this design proposal is the inclusion of tree nurseries and "Mechanical Trees" to capture carbon dioxide, which we consider another form of energy production (by offsetting extra energy used to mitigate the impact of the increasing CO2). There are 1,430 units of "Mechanical Trees," which absorb about 7,865 metric tons of carbon dioxide annually. This amount is equivalent to CO2 emitted by 1,709 passenger vehicles in one year (a typical passenger vehicle emits about 4.6 metric tons annually, EPA).

In addition to the "Mechanical Trees," real trees effective in sequestering carbon are planted in the park. 129 Live Oak trees, 126 London Plane trees, and 182 Chestnut trees will absorb carbon for the next two decades while providing a respite to its surrounding residents. On average, these trees can absorb up to 40 kg of Carbon Dioxide per year. Based on this calculation, all of the trees in the park can remove about 17 tons of CO2 per year. **The overall park can remove about 7,882 metric tons of carbon annually**.

Altogether, the Productive Frictions: E3 (Energy/Ecology/Economy) project explores how synergies between the production of energy, ecology, and economy can emerge through redesigning a large decommissioned brownfield site. E3 builds on the strengths of the existing communities surrounding it, including its history and changing demography.

The park's design is inclusive, and residents and visitors of all ages can enjoy a range of programs spread within the park. For example, the carbon sequestration tree nursery located on the west side of the site provides restful green spaces for walking, picnics, and other quiet and slower activities.

Other green areas include the community garden that engages local garden organizations (Verein der Gartenfreunde) that encourages residents' engagement with growing food and plants. Additionally, animal therapy program encourages the public's interactions with animals. Some examples are cow cuddling, goat yoga, equine therapy, therapy rabbits, and chickens. In addition, these animals provide animal waste for biodigesters that produce green energy.

The site's east side is dedicated to more active programs such as running tracks, BMX bike tracks, skate parks, and water pool that encourage lively outdoor activities. The E3 poles are intertwined with all these programs while energy, ecology, and economy are in production on site.

The production of culture as an outcome of the synergies brought about by these programs, and 838 E3 (Energy/Ecology/Economy) poles are immense. The E3 project addresses the following UN Sustainable Development Goals: "7. Affordable and Clean Energy," "9. Industry, Innovation, and Infrastructure," "11. Sustainable cities and communities," and "15. Life on Land" that contributes to a better future for Mannheim and beyond.

**300-word Environmental impact summary**

The **Productive Frictions: E3 (Energy/Ecology/Economy)**project primarily produces renewable energy and sequesters significant carbon. Overall this is beneficial to the immediate site and its larger surrounding. Potential carbon emission from life stock is mitigated as it engages 'new carbon' (relatively rapid biogenic natural cycle) as opposed to the 'old carbon.' The adverse impact of renewable modes of energy production (solar, micro wind turbine) is minimal. The ecological benefits of planting 437 new trees, providing clean energy, and animal habitat through bird nest modules add to the positive environmental impact of the proposal. Overall, the cost of the project will be paid off with the energy it produces and the carbon it captures. Moreover, it generates green economic activities for the local communities and businesses. Further, it is a worthwhile project in that it facilitates a shift towards a positive perception of energy-producing infrastructure at a local scale. This project also becomes an exemplary prototype project that can be replicated elsewhere.