****

Food for the biosphere and the technosphere

**Photosynthesis** is a metabolic process that enables plants to synthesize its own **food** out of **CO2**, **water** and **sunlight** as the primary energy source. What if this concept is applied to urban spaces in the form of a modular canopy garden half-way nature and technology? CROPERGY combines three systems to harvest energy from the same natural sources used by plants: The **sun**, through Organic Photovoltaic Panels **OPVs**; **water** and **CO2**, through **PBR systems** (**Photo Bioreactor**); and **soil**, through **PMF-C** systems (Microbial Fuel Cells). This hybridization re-formulates the notion of human energy production to include food in addition to electricity. Thus, CROPERGY is designed to produce power available in KWh, and food in kilocalories for direct human consumption. The basic petal module of the canopy garden proposed **multiplies the crop production area** by allowing plants to grow on the ground and also hanging. The design resembles the petal of edible flower ***Hemera Kallos***, which is planted locally and will be exhibited during the BUGA23. Single petal modules can function as discrete pieces of urban furniture or pergolas and greenhouses when assembled to fit specific site and function requirements. CROPERGY will meet the energy demand of **42%** of the new inhabitants in the study area, and bring new insights into the link between water, plants, and power generation in the cities of tomorrow.

It is estimated that by **2050**, the world population will reach **9 billion**, which would require a **70%** increase in food production all over the world.[[1]](#footnote-0) This scenario calls for efforts to guarantee **energy and food security** in every country. Currently, **30%** of the energy produced worldwide is used in **agricultural production**. Particularly, Germany uses more than **50'000,000 ha** for the consumption of agricultural products, i.e. almost three times its national agricultural area (**17'000,000 ha**), which represents an indirect impact in terms of deforestation. Between **2000 and 2015** every German needed **80m2** of soil to be fed[[2]](#footnote-1). This is more critical with the fact that only **1/3** of the vegetables consumed by Germans are grown in Germany. That is to say, if today all **13.6 ha** of *Spinelli Park* were cultivated, they could only feed **1,888.8 inhabitants [[3]](#footnote-2)** annually. With the CROPERGY system these 13.6 ha would supply the demand of **5,700 inhabitants.** The cultivation of vegetables contributes to **mitigating climate change**, with the additional value of relying on solar energy, the primary source of renewable energies on the planet. The proposed system will avoid the emission of **112.8 tons** of CO2, capture **119 tons[[4]](#footnote-3)** of CO2 annually, and purify approximately **2 Olympic swimming pools** (6.205m3) of gray water on an annual basis.

**The roots**

The shape of CROPERGY was inspired by the edible flower **Daylily** (*Hemerocallis*, a Greek name composed by the words *hemera* (day) and *kallos* (beauty) symbolic of *Luisenpark*, which is located next to *Spinelli Park*. Three typologies were developed via different grouping patterns. The **petal** functions in the smaller scale as a piece of urban furniture. The **stem** is comprised of several petals that create pergolas along pedestrian walkways. The third one corresponds to the radial grouping of five petals to assemble a module that together create a large **flower**, giving rise to greenhouses and large activity centers.

To locate the modules, the design team studied **meteorological and energy data** from the city of Mannheim. **Pluviosity**, **solar radiation** and **wind patterns** were analyzed. After weighting the variables, the design team concluded that the most favorable location area is the central part of the site, and the most advantageous pattern is a **radial** one. This creates a versatile network that allows for different module assembly possibilities. The continuous envelope resulting from module addition helps to create and maintain controlled **microclimates.** This grouping principle fosters the cultivation of high-quality products with up to four harvests a year, that is, two to three times more production than a traditional harvest. This approach favors the relationship with the Green Corridor: **Klimopass**, which connects several important parks in the city according to the **landscaping approach** considered by the **BUGA**. This transforms urban settings like *Spinelli Park* into an iconic environmentally sustainable place, benefiting the new households and reducing the negative impacts of global warming. With CROPERGY, existing parks can be turned into edible parks.

For the **community manufacture** of a petal[[5]](#footnote-4) prototype , a 15 x 20 cm **laminated oak wood** structure will be assembled, taking advantage of the fact that **BUGA 23** will have a cultivation area for timber production. Two **pipes** are arranged on the structure, one of 2" for the algae, and the other of 4 ½" made with **biopolymers** for aeroponic cultivation, where the ¼" irrigation system and the roots of the plants will be located. Subsequently, a bioplastic that will be manufactured from agricultural waste will be used to enclose the greenhouses.[[6]](#footnote-5) Organic Photovoltaic Panels **OPVs** are assembled as the final envelope. Finally, the pipes will be connected to the **motor pumps** and the **PMFC** system and the **biomass filtering system** will be installed. Materials and procedures that together reduce the amount of **embedded energy**. These characteristics allow CROPERGY to be **prefabricated**, **easy to build**, **maintain** and **transport**. The design can be implemented in different climatic and geographic settings and can be **adapted** according to the site needs. For its execution, the approximate cost of a **prototype** is estimated to be 1.525,66 €. As for maintenance, it will be required regular cleaning of the pipes, which have their own inspection system. Additionally the modules would be in their best optimal conditions by inspecting regularly the motor pumps and essentially the care and supervision of the crops.

**Energy sources**

* 1. **Aeroponic System**

This method mainly requires water rich in nutrients to irrigate the plants, electricity to power up the motor pumps that allow the operation of the PBR and the sprinkler system. These requirements are met by applying two technologies that don't emit CO2. They are explained below.

* 1. **Solar energy**

Solar energy is used for the operation of the motor pumps and the water sprinkling system. Solar radiation is captured by **OPVs.** These panels can be recycled, reducing the amount of waste.

* 1. **Water cycle**

The city´s gray water is purified by the *Chlorella* microalgae in the **PBR** and then incorporated into the irrigation system. The water that is mixed with microalgae undergoes a filtration process that results into water and biomass. The latter can be a source of economic incomes for the community in the form of biogas, biofertilizer, heating or public lighting via a bioluminescence organism, the *Pyrocystus fusiformis* microalgae.

* 1. **Crop energy**

For the greenhouse lighting, a third technology is incorporated, using microbial plant fuel cells that generate energy through an electrochemical exchange via a system of anodes and cathodes. The plant-microbial fuel cell (P-MFC), developed, tested, and validated by European companies, is a promising technology that converts solar energy into bioelectricity with the plant-microbe interaction in the rhizosphere region of a plant. The photosynthetic root exudates act as a substrate for rhizosphere bacteria. These microorganisms can thus generate bioelectricity by avoiding external substrate replacement, making this technology more efficient compared to conventional microbial fuel cells.

The combination of these three systems will produce the total amount of **196,42 MW** [[7]](#footnote-6) that would maintain the constant operation of the greenhouse and would generate an annual surplus of **156.58 MW**. In terms of food security, **400gr** of vegetables is recommended on the daily diet of a person, which equals **146 kg** per year. CROPERGY would supply the recommended vegetable intakes of **5700 [[8]](#footnote-7) young adults**, which is **42.2%** [[9]](#footnote-8) of the population living in the **4500** new houses.

**Harvesting**

CROPERGY provides an inter-generational gathering environment for food growth and a harmonious **human-ecological** relationship. The project will have **gardening areas**, **community kitchens** and facilities to run training **courses on alternative agriculture methods.** People will engage in other sustainable activities like composing, reducing the environmental impacts related to food transportation[[10]](#footnote-9).

CROPERGY's goal is to trigger a **bioeconomy** that **reduces** the **city's ecological footprint** by **capturing** large amounts of **CO2** and purifying a considerable percentage of the city's gray water. The proposed structures are **biodegradable** and **easy to operate** regardless of age or education level.

**ODS**

* 1. **Goal 2.** Food security and improved nutrition
  2. **Goal 3**. Ensure healthy lives and promote well being for all ages
  3. **Goal 4.** Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
  4. **Goal 6**. Ensure availability and sustainable management of water and sanitation for all
  5. **Goal 7.** Ensure access to affordable, reliable, sustainable and modern energy for all
  6. **Goal 8.** Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
  7. **Goal 9.** Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
  8. **Goal 11.** Make cities and human settlements inclusive, safe, resilient and sustainable
  9. **Goal 12**. Ensure sustainable consumption and production patterns
  10. **Goal 13.** Take urgent action to combat climate change and its impacts
  11. **Goal 15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Faced with Germany's dilemma of whether to continue with an agricultural model that impacts ecosystems, the design team envisioned CROPERGY as an alternative for the production of the most essential energy for human beings: food. It evolves the traditional greenhouse, which is **95%** more efficient than an open-air crop. However, the arable area depends entirely on the total footprint of the greenhouse and tends to lower the quality of the soil and food over time. CROPERGY **triples the arable area** by allowing crops to grow on the ground, on the inner sides of the module envelope and on the envelope pipes. In addition, it allows the production of heat energy all year round, regardless of the seasonal changes. It incorporates **three** renewable energy sources for its operation and an aeroponic cultivation system that increases productivity by **85%.** Consolidating CROPERGY as the seed to harvest new possible futures.

1. <https://thermtest.com/latinamerica/diseno-de-invernaderos-que-aumentan-la-conductividad-termica-del-suelo-y-los-indices-de-produccion-al-tiempo-que-combaten-el-cambio-climatico> [↑](#footnote-ref-0)
2. Documentary source Bioeconomy as an alternative - “¿qué tan prometedores son los recursos renovables? DW” [↑](#footnote-ref-1)
3. <https://www.fao.org/3/y1669s/y1669s09.htm> [↑](#footnote-ref-2)
4. Greenhouse crop plants absorb about 10 tons of CO2 per hectare per year. [↑](#footnote-ref-3)
5. Enter to the QR code [↑](#footnote-ref-4)
6. <https://www.redalyc.org/journal/933/93368279005/html/> [↑](#footnote-ref-5)
7. Considering that the area of OPVs panels per petal is **20 m2**, **0.02428MW/Year** can be produced. Therefore, 1700 modules will produce **41, 2 MW/Year**, of which **0.12MW/Yea**r is consumed by 18W DC submersible micro pumps to pump water with microalgae and crop water. Therefore, there is a surplus of **41.038MW/Year**.

   Taking into account the estimations made by the european company, we can conclude that in the algae pipeline of each petal corresponding to **0.1m3**, **5.5 kg** of biomass can be produced annually, which is equivalent to **0.066 MW/Year**, i.e., for the 1700 petals a total of **112.4 MW/Year** can be obtained.

   Considering that on average each petal has **8m2** of arable land and that per **1m2** produces **3.15 MW/Year** producing a single petal **0.00252 MW/Year** and the whole set **4.284 MW/Year**. This energy that would be used for urban lighting. Leaving a surplus of **3,128MW/Year**. [↑](#footnote-ref-6)
8. Considering that the arable area of each petal for vegetable growth is 8m2, **165377 Kg** can be obtained in the whole set, in vegetable crops such as lettuce, spinach, broccoli, zucchini, among others, reinterpreting this into amounts of energy as **77576.41 Kcal/year.** While **378 kg** per year can be obtained in aeroponic crops, which corresponds to **68040 Kcal/year** per petal. Finally, the sum of both crops would produce **831413Kg**, that is, **145,616.41 Kcal/Year**. [↑](#footnote-ref-7)
9. Considering that the average German family is comprised of 3 members. [↑](#footnote-ref-8)
10. Local agriculture is focused on grains and legumes production therefore representing 29.6% of the arable surface, while vegetables and fruits constitute only the 3%, ranking at the bottom of the German cultivation data, covering only one third of the demand for vegetables and one fifth of the demand for fruits of its citizens and therefore must be imported to be sold at high prices that turn out to be almost double or triple compared to a kilo of wheat. [↑](#footnote-ref-9)