

BIOTOPE

# SOLAR ENERGY AND WATER FOR ALL

## From BIOTOPE to Life-Sustaining Infrastructure

Bionic Principles for Food, Water, Energy and Human Habitat

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Humanity must provide enormous additional quantities of food, water, energy and living space while rapidly reducing greenhouse-gas emissions, material consumption and fossil dependence. This is not a marginal field: buildings and construction account for around 37% of global CO<sub>2</sub> emissions and nearly 50% of global material extraction. This approach does not propose a new Nature. It proposes learning from the one that already exists. Living systems achieve extraordinary effects with lightweight multifunctional structures and coupled flows of matter and energy. BIOTOPE translates this bionic principle into technology: light, heat, air, water, plants and solar energy are not treated as separate sectors but intelligently connected. Much is already proven: durable ETFE lightweight envelopes, large transparent structures, photovoltaics, solar thermal energy, thermal storage, evaporative cooling, aquaculture, sensors and controls. The new task is their systematic integration into simple, affordable, decentralized and life-serving infrastructure. The Generalized Fermat Principle provides the guiding question: How can we achieve the greatest life-serving effect with the least necessary input of primary energy, material, technical complexity and irreversible intervention? Correctly applied, ecology and economy cease to be opponents and become two sides of the same coin. The planned 2,000 m<sup>2</sup> BIOTOPE Demonstrator in India can become a first larger seed: build, measure, learn, simplify, reduce cost, add functions and replicate.

We do not need to build a second Sun. We need to become much more intelligent in what we do with the photons of the one we already have.

New digital manufacturing methods strengthen this path: topology optimization and 3D printing can shape structural nodes, ribs and lattice structures so that material is placed specifically along real load paths. At the same time, large-scale BIOTOPE agriculture can enable additional photosynthesis; durable climate benefit from CO<sub>2</sub> uptake is achieved especially when part of the additional biomass is transferred into long-lived biogenic products and building materials.

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**Jürgen Kleinwächter**

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Bionic Principles for Food, Water, Energy and Human Habitat

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**1. Bionics - not copying Nature, but understanding it** A leaf is simultaneously a light receiver, chemical reactor, transport system, gas exchanger and evaporative cooler. A wasp nest achieves protection and thermal buffering with very little material through lightweight multilayer structures. We cannot copy Nature's immense complexity. We can understand its operating principles, simplify them technically and reconnect them into multifunctional cooperating systems.

How can we achieve the greatest life-serving effect with the least possible primary energy, material, technical complexity and irreversible intervention?

**2. BIOTOPE - simple components, complex overall function** BIOTOPE deliberately uses simple basic elements: transparent multilayer envelopes, air channels, movable louvers and PV modules, flaps, fans, water circuits and heat exchangers. Its technological intelligence lies not in a single component but in the organization of their interactions. Light supports plants and electricity generation; heat is used or stored; evaporation cools; humidity can be condensed; water feeds plants, stores heat and cold and can produce food through aquaculture.

One structure - several functions. One energy flow - several successive uses.

**3. Essential building blocks are already reality** Large ETFE lightweight envelopes have existed for decades. The Eden Project in Cornwall demonstrates large three-layer ETFE cushions with extremely low weight, UV transmission and a non-stick, self-cleaning surface. In 2026 AGC documented an agricultural greenhouse using F-CLEAN fluoropolymer film continuously for 36 years without replacement. Our earlier Fix-Focus work also demonstrated that lightweight solar concentrators can generate high temperatures, melt metals and shift high-temperature heat in time through stationary cavity storage.

The instruments are largely on the table. The next innovation is their systematic bionic integration.

**4. From dual use to multiple use** Agri-PV already demonstrates the attraction of using the same land for agriculture and electricity. BIOTOPE extends this logic: food + electricity + heat + water management + cooling + climate protection - and, later where appropriate, human habitat. Not every application needs every function; this is precisely the strength of modularity.

How many separate infrastructures can one intelligently designed, solar-driven and multifunctional structure replace, reduce or connect?

## CONVENTIONAL BIOTOPE-INSPIRED

Extraction → transport → high-temperature Sun → lightweight adaptive envelope processing Light → plants → food Heavy envelope → heating → cooling PV → electricity · heat → storage Electricity → water → food supply Evaporation → cooling · water → aquaculture

**5. From greenhouse to living structure Large lightweight BIOTOPE envelopes can contain different climate zones. Humid plant compartments can be separated by transparent internal membranes from working, communal or later residential areas. Water reservoirs can simultaneously serve as water supply, heat/cold storage and aquaculture. The outer envelope can protect, insulate, control light, generate electricity, collect heat, guide air and support cooling. A passive building skin becomes an active functional organ.**

The greenhouse would then not be the final product of BIOTOPE, but its first demonstrator.

**6. Lightweight construction attacks material, energy, transport and safety together Material that is never installed does not need to be extracted, processed, transported or later disposed of. Lower mass reduces structural loads and can reduce foundations and transport. A further physical difference is elementary: mass that is not placed above people cannot fall on them as tonnes of collapsing material. Lightweight structures must of course be correctly engineered for wind, fire, ageing and local loads - but reducing the destructive mass available in a failure is real.**

Do not use a tonne intelligently where ten kilograms can reliably perform the same life-serving function.

### **Digital Bionics - Material Only Where Function Requires It**

Additive manufacturing connects directly with our lightweight principle. Topology optimization calculates from real loads where material is required to carry forces - and where it is not. 3D printing can then produce complex nodes, ribs and lattice structures that would be difficult or expensive to manufacture conventionally. For BIOTOPE this opens a path toward extremely lightweight, locally and increasingly automatically produced structural and connection elements combined with durable membrane envelopes.

**Material only where function requires it.**

**7. The fusion reactor is already above us The Sun supplies the decentralized energy flow with which life has worked for billions of years. Photons grow plants, generate electricity and heat. Heat can be stored; evaporation cools; water vapour can condense; water stores heat and cold. This is not exotic physics but optics, thermodynamics, fluid dynamics, plant physiology and control engineering. The new step is their systematic cascading.**

Collect - Use - Store - Reuse.

**8. Ecology and economy become congruent Less material means lower material cost. Less transport means lower transport cost. Less energy means lower energy cost. One structure performing several functions can replace additional structures. Long life reduces replacement. Repairability reduces waste. Local production shortens supply chains and creates local value. Closed cycles reduce losses.**

**The Generalized Fermat Principle therefore connects ecological and economic optimization.**

Ecological efficiency becomes economic efficiency.

**9. India - demonstrator and accelerator** India combines enormous demand for affordable food, water, energy and future living space with abundant solar radiation and a powerful, cost-effective manufacturing base. The planned 2,000 m<sup>2</sup> BIOTOPE Demonstrator can therefore become more than a greenhouse: a Living Laboratory. We measure yield, water, electricity, heat, cooling, material, cost, maintenance and lifetime. Then we simplify, localize production, add functions and replicate.

Together with our Indian partners, develop the BIOTOPE that India can build itself.

**10. From individual modules to decentralized networks** This approach does not need to design a finished future city. One module is built, measured and improved. More modules follow. Food, water, heat, electricity and information are generated locally and exchanged between units. Autonomy does not mean isolation, but the ability to cooperate without existential dependence. Small intelligent decentralized life-supporting structures can grow into larger resilient networks.

Hypothesis - Demonstrator - Measurement - Learning - Improvement - Replication.

**11. The metric: total life-serving effect** Component efficiencies remain important, but they are not enough. We also need a system metric: kg food, litres of water, kWh electricity, kWh useful heat, cooling effect, material mass, CO<sub>2</sub>e, investment, maintenance and lifetime per square metre. This makes the Generalized Fermat Principle measurable.

Life-serving effect per unit of primary resource.

### **BIOTOPE as a Carbon Pump - Photosynthesis Plus Durable Storage**

Large-scale BIOTOPE agriculture can increase biological production through optimized light, water, temperature and CO<sub>2</sub> conditions. Additional atmospheric CO<sub>2</sub> supplied to the system is fixed into biomass by photosynthesis. For a durable sink effect, however, growth alone is not enough: if biomass is quickly eaten, burned or decomposed, much of the carbon returns to the cycle. The particularly powerful pathway is therefore to connect increased biomass production with long-lived biogenic materials and products.

**LESS CARBON OUT + MORE CARBON STORED = a double climate effect.**

**12. A major partial solution - not a niche technology** BIOTOPE alone will not solve climate change. But if the same architecture reduces material demand, embodied energy, fossil operating energy, transport and water losses while simultaneously providing food, electricity, heat, cooling and protection, it addresses several major drivers at once. This makes it a potentially important partial solution - provided we industrialize it, reduce cost and deploy it at scale.

BIOTOPE is not interesting because it performs one task slightly better. It is interesting because one simple architecture may perform many essential tasks together with dramatically less primary input.

**13. From the sorcerer's apprentice to a conscious part of Nature**  
**Humanity possesses enormous technological power, but also the ability to understand, reflect and choose consciously. This approach therefore means neither retreat from science nor romanticization of Nature. It means understanding, learning and cooperation. Intelligence alone is not sufficient; it needs compassion - respect for the extraordinary phenomenon of life of which we ourselves are part.**

Not domination of Nature, but consciously growing into a more intelligent, resilient and life-worthy structure.

WE ALREADY HAVE WHAT WE NEED The Sun exists. Lightweight envelopes exist. Solar concentration, photovoltaics, thermal storage, evaporative cooling, aquaculture, sensors and intelligent controls exist. Plants have transformed sunlight, CO<sub>2</sub> and water into complex living structures for billions of years. What remains is to connect what we already know into simple, lightweight, affordable, locally producible and life-serving systems. Curiosity as our drive. Natural science as our tool. Bionics as our teacher. The Generalized Fermat Principle as our engineering guide. Compassion as our responsibility. Humanity as our direction. And perhaps the next major step begins very simply: 2,000 square metres in India. A seed. And seeds have a remarkable property: they grow.

**CURIOSITY → SCIENCE → BIONICS → FERMAT → COMPASSION**

**Sources / technical reference points • UNEP / GlobalABC, Global Status Report for Buildings and Construction 2025-2026 (2026): around 37% of global CO<sub>2</sub> emissions and nearly 50% of global material extraction. • Eden Project, Architecture: three-layer ETFE cushions; less than 1% of the weight of an equivalent glass area; UV transmission; non-stick/self-cleaning surface. • AGC, 21 July 2026: F-CLEAN agricultural greenhouse film recognized for 36 years of continuous use without replacement. • Earlier Fix-Focus development work by Jürgen Kleinwächter: concentrated solar heat, high-temperature experiments and thermal storage.**