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STP

Shared lessons

Designing with/for Nature & Prototyping

IAAC
Chiara Farinea & Fiona Demeur

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SECTION
ONE

General Concepts & Strategies

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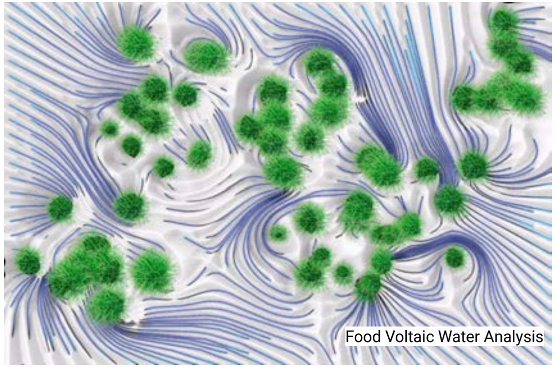
Parametric Design



Food Voltaic Water Analysis

Parametric design is an approach to design that utilizes **parameters and algorithms** to create and modify designs. The designer defines the relationships between different elements within a design using specific parameters, rules, and constraints.

Benefits include:

→ Easy to modify or explore ideas
→ Increase efficiency in iterative design - Multiple changes can be implemented at the same time.
→ Creating complex geometries
→ Optimising designs e.g for fabrication, to maximise shade, etc.

General Concepts & Strategies

Participatory Design

An approach that involves end-users, stakeholders, and designers working together in the design process to create solutions that **meet the needs and preferences of the end-users**. It aims to ensure that the design is user-centered, inclusive, and reflective of the diverse perspectives and experiences of those involved.

Benefits include:

- → Working directly with end users, empowering them and giving them ownership
- → Enhanced creativity and innovation through working with experts
- → Builds relationships between the different stakeholders

This is often achieved through workshops, brainstorming sessions, interviews, surveys etc.

Digital Fabrication

CO-mida Prototype
https://iaac.net/project/co-mida/

Digital fabrication is a modern manufacturing process that involves using **computer-controlled machines and tools** to create physical objects from digital designs. It combines computer-aided design (CAD) software with various fabrication technologies such as 3D printing, CNC milling, laser cutting, and more.

Benefits include:

- ➔ Greater design flexibility
- ➔ Faster production times
- ➔ Cost-effective customised objects

The object is digitally designed and then converted into a g-code that the digital fabrication tool can read for fabrication.

Green Walls


CO-mida Prototype
https://iaac.net/project/co-mida/

Green walls are **vertical structures covered with live plants** that are grown vertically on a building's exterior or interior surfaces.

Benefits include:

- → Environmental benefits
- → Aesthetic appeal
- → Space optimisation
- → Encouraging biodiversity
- → Noise reductions
- → Improved well-being

Green walls can be built through a variety of systems and should be adapted based on the needs of the plants.

Biophotovoltaic Systems

A specialized branch of **biotechnology** and renewable energy research that seeks to **generate electricity** directly from plants or microorganisms that can perform photosynthesis.

Benefits include:

- Environmental benefits
- Combining green elements (roofs, walls etc.) with energy production
- Currently, LED's and sensors can be powered through this system.

This is an emerging field and therefore a lot of research is still being done to understand the full potential. If you are curious to know more check out the work of Plant-e.

Mycelium

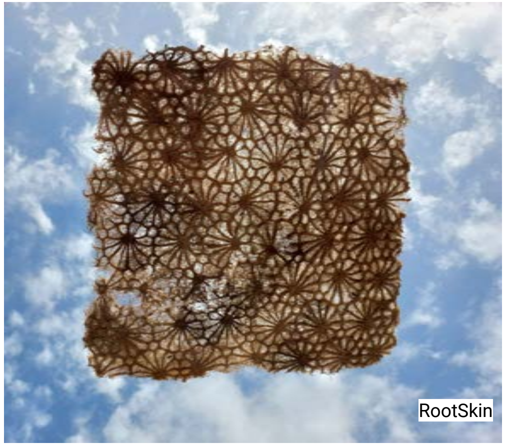
Mycelium is the dense, thread-like network of fine structures called hyphae that make up the **vegetative part of a fungus.** It requires specific conditions to grow.

Benefits include:

- → Providing a food source
- → Bioremediation - absorb or breakdown toxins/pollutants (some species)
- → Structural properties
- → Producing biomaterials
- → Acoustic insulation

Mycelium has become a popular material in design and will continue to be popular given the nature of the material and its properties.

Bio-textiles



Biotextiles are a class of **textiles or fabrics** that are made from **living organisms or natural materials**, typically incorporating biological components such as bacteria, fungi, algae, or proteins

Benefits include:

- → Waste reduction
- → Biodegradable & sustainable
- → Lower environmental footprint (depends on additives and the processes)
- → Customisation

While biotextiles hold great promise, there are still challenges to address, such as scaling up production, ensuring consistent quality, and overcoming regulatory hurdles in various applications.

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Phytodepuration

Bio-MON
Maya Mohan, Ozge Tektas,
Nusrat Tabassum

Phytodepuration, also known as phytoremediation, is an eco-friendly and natural approach to purifying or remediating polluted water or soil using plants and their associated microorganisms. The process harnesses the unique abilities of certain plant species to absorb, accumulate, and transform pollutants present in the environment.

Benefits include:

- ➔ Environmentally friendly
- ➔ Cost effective
- ➔ Aesthetic and recreational value
- ➔ Habitat restoration

However, this solution does not work for all contaminants.

SECTION
TWO

Prototyping

Prototyping

What is Prototyping?

Definition:
the **first example of something**, such as a machine or other industrial product, from which all later forms are developed (Cambridge University Press, 2011)
Prototypes can be physical or digital.

In design prototyping is used for:

- → To test concepts or ideas
- → To test the devices performance
- → To better visualise or communicate
- → To evaluate the different aspects of the design

In some cases before the prototype, there is a pretotype which is a quick and messy version of the idea to to quickly test the solution.

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Prototyping

How can designers prototype?

How can **digital technologies** support us to design cities where we **integrate living systems** making the urban environment more **resilient** and **ecosystems stronger**?

With the constant development in technology, the way in which designers can prototype continues to evolve. Access to digital fabrication technologies and a wide array of digital tools can increase efficiency and allow for quick iterations or analysis.

Digital fabrication tools for prototyping:

- → Lasercutting
- → CNC Milling
- → 3d Printing
- → Robotic Fabrication

Prototyping: Digital Fabrication

Lasercutting

- → Subtractive Manufacturing with the use of a laser beam
- → Lasercutting is used to cut out pieces, or to engrave into materials.
- → Different materials require different levels of power from the machine so it is always important to test.
- → A 2D file with lines must be generated in order to lasercut.
- → 2-axis

SECTION **TWO**

Prototyping: **Digital Fabrication**

CNC Milling

- Subtractive Manufacturing
- Material is placed on the bed of the CNC machine and the milling bit removes and cuts away material.
- Parameters that must be set include, type of milling bit, the cutting speed and how fast the spindle with the milling bit rotates.
- It is a fast and precise way of removing material.
- 3-axis but can be more

SECTION **TWO**

Prototyping: **Digital Fabrication**

3D Printing

- → Additive Manufacturing
- → There are different types of 3d printers, but the most common is extrusion based.
- → A variety of materials can be used including, plastics, clay, resins, biomaterials etc.
- → Parameters to consider when 3d printing include layer height, printing infill or not, and whether supports is needed for the design to be printed.

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Prototyping: Digital Fabrication

Robotic Fabrication

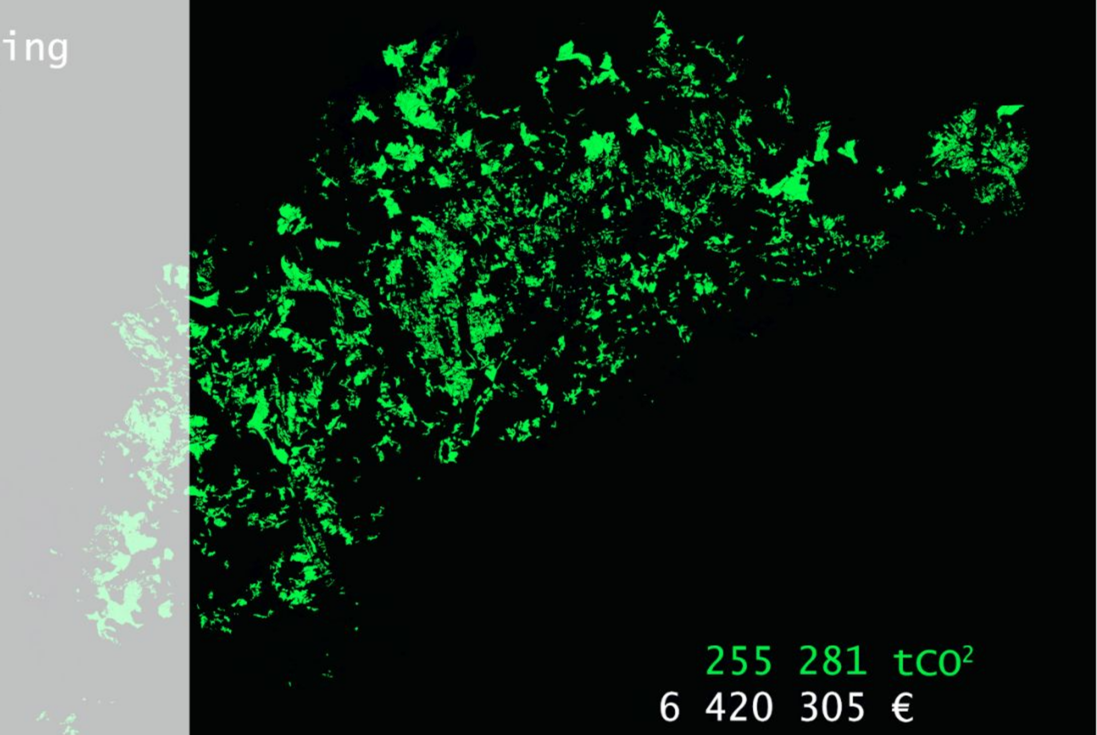
- Additive or Subtractive Manufacturing - depends on the tool attached
- Robots can be used for 3d printing, milling, picking up objects etc.
- The 6-axis robotic arm gives the designer more freedom to introduce complex designs.
- Robotic arms come in a variety of sizes which allows designers to work at different scales.

SECTION **TWO**

Prototyping

Digital Tools

- Digital tools include simulations and computation to support design
- When working at the urban scale, simulations and computation are used to analyse the current state, visualise the proposal, and analyse the impact.
- Using real and accessible data allows designers to propose solutions that will have an impact



Master in City & Technology 2020/21, Internet of Cities,
Faculty: Mathilde Marengo, Eduardo Rico, Assistants: Iacopo Neri, Raul Bielas,
Students: Kevin Aragon, Iñigo Esteban, Diana Roussi, Tugdual Sarazin
https://www.iaacblog.com/programs/breathing-organism/

Prototyping: Capitalising on Digital Fabrication

Opportunities

- ➔ Additive and subtractive manufacturing allows you to make as many unique elements as you want because no mold is required
- ➔ Softwares used for digital fabrication are linked with parametric design softwares which allows for changes to be easily implemented, with instant updates
- ➔ With digital fabrication technologies, designs can be pushed and intricate textures achieved

SECTION
THREE

Designing with/for nature

Designing with/for Nature: **Beyond Human Centered Design**

Even though the example of natural ecological systems reveals that mutualistic attitudes can help to shape the ecosystems, ultimately making them stronger, longer-lived and more resilient, up to now **multispecies co-existence** and **collaboration** have not really been planned or embedded in the development of our cities.

What if we start to design spaces not centered only on humans, but on the future of the whole biosphere?
What if we embed humans-flora-fauna and bacteria collaborations in the morphology and materials of our cities fostering collaborations towards resilience strengthening?

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Design Parameters & Considerations

- Lighting requirements →
    - How much sun or shade?
- Water requirements →
    - How much does it rain?
    - Will an irrigation system be needed?
- Amount of soil →
    - How big does the pot have to be?
- Companion species →
    - Which plants grow well together?

Design Parameters & Considerations

- What kind of habitat do they usually live in? →
  - shape, size, material
- Do they like to be isolated or are they happy to have neighbours?
- Is the area of implementation their natural habitat or will they need to be encouraged to come there?

Design Parameters & Considerations

- Automated watering system →
  - How many times will it need to run per day?
  - What happens if it fails?
  - What happens if it overflows?
  - How big do the tubes need to be to get the right amount of water?
  - Will there be sensors?
- Manual watering system →
  - Who will water the plants?
  - How many times a week?

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SECTION
FOUR

NBS Case Studies

NBS Case Studies: **Mutualism**

USE THE PANELS

Overview:

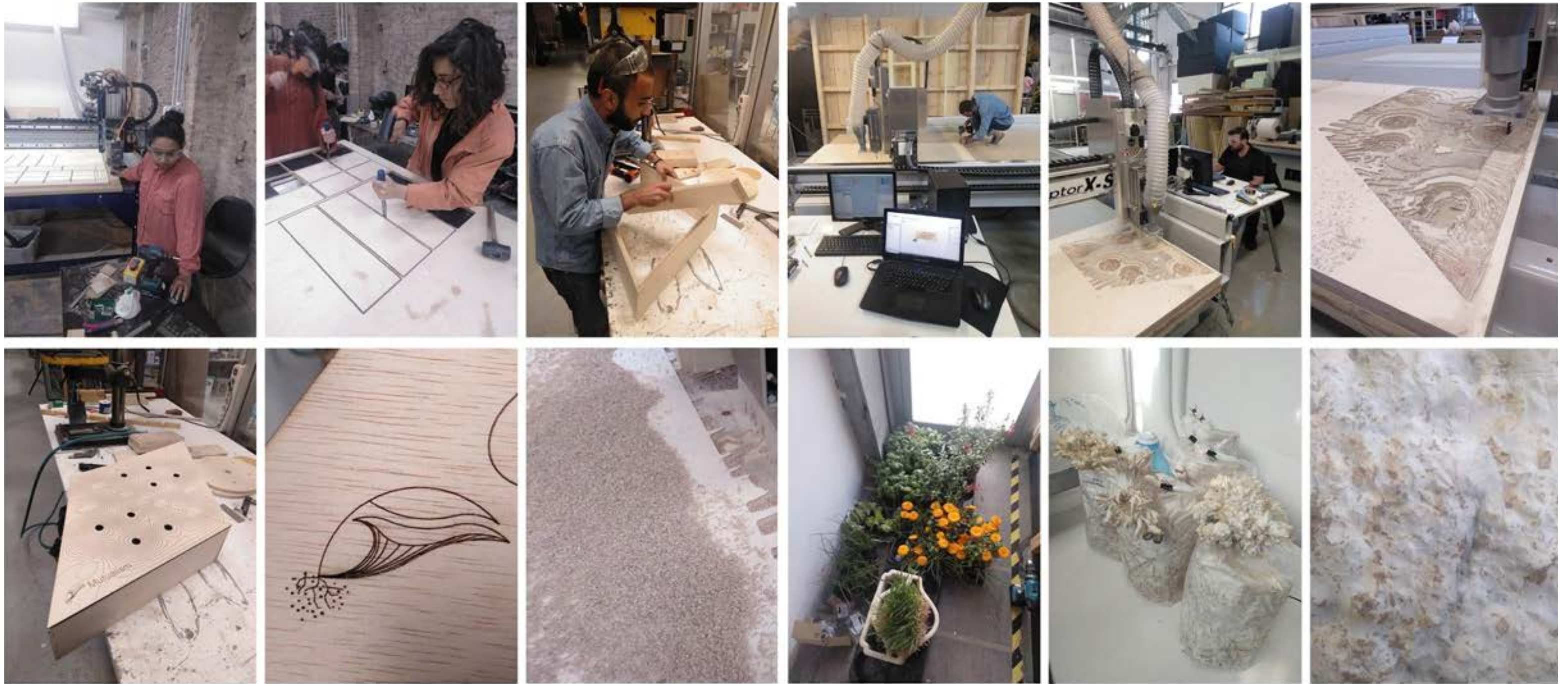
Mutualism is a **modular system** which supports the growth of mushrooms on one side and the growth of plants on the other. These modules can be implemented in the public space. The structure's modules allow for both food and construction materials to be produced.The external surface is **parametrically designed** and tailored to **control the environmental conditions** and provide the right growing conditions. Digital fabrication processes were used to mill the plywood panels using a **CNC machine**.

Advanced Architecture Group & Participants of the Creative Food Cycles Workshop

SECTION **FOUR**

NBS Case Studies: **Mutualism**

Fabrication



NBS Case Studies: **Mutualism**

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NBS Case Studies: **CO-mida**

Overview:

CO-mida combines **nature-based solutions** with **robotic 3D printing technology** and **digital technologies** to create an automated green wall. Installed in a community garden, the wall is maintained by the community with the aim of growing food, providing homes for birds, bats, and insects, and generating electricity through a **bio photovoltaic system**.

In addition, there are **sensors** incorporated in hubs that measure the air temperature and the amount of energy produced by the bio photovoltaic system.

For more information:

https://iaac.net/project/co-mida/

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NBS Case Studies: **CO-mida**

Co-designing CO-mida

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NBS Case Studies: **CO-mida**

NBS Case Studies: **CO-mida**

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NBS Case Studies: Vertical Food Farm

Overview:

This project was designed through a **participatory process**, with students, children and experts. While design the wall, the students had to take into consideration the needs of the children, but also those of the **plants, insects and birds**. The surface of the pots were designed to foster **spontaneous growth** and house moss.
The ceramic pots were designed with **parametric tools** and digital fabrication using a clay **3d printer**.

For more information:
https://iaac.net/iaac-at-the-smart-city-expo-world-congress/

Advanced Architecture Group, LaMáquina by Noumena
Students: Divya Shah, Harshul Goti, Mara Muller, Mira Housen

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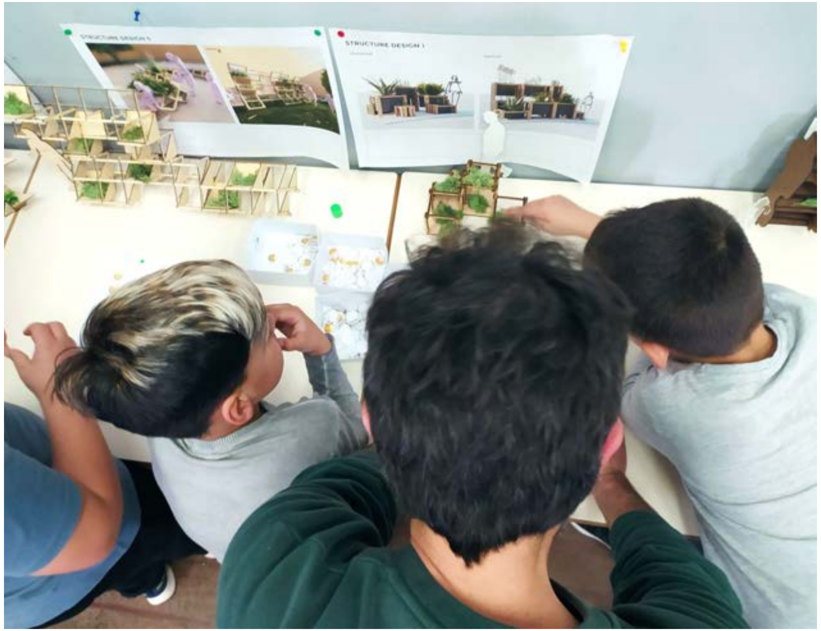
SECTION **FOUR**

NBS Case Studies: **Vertical Food Farm**

Children of Porto evaluation the IAAC Students' work



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NBS Case Studies: Vertical Food Farm

➔ This project will be installed in two schools in Porto where the children and teachers will cultivate learning how to grow food and look after plants.

Advanced Architecture Group, LaMáquina by Noumena
Students: Divya Shah, Harshul Goti, Mara Muller, Mira Housen

NBS Case Studies: **Food Voltaic**

Overview:

Food Voltaic consists of an **urban infrastructure** targeted to enhance the cities resilience. Through **digital fabrication and tools** the system enhances and exploits the properties of living materials.
The external surface has been designed using **parametric programs** and can be **adapted to the local conditions**. The tile sits in a box that is equipped with a **biophotovoltaic system**, collecting the electrons emitted by bacteria near the roots of the plants, as well as sensors to monitor soil moisture, temperature, humidity, air quality and quantity of energy produced by the system.

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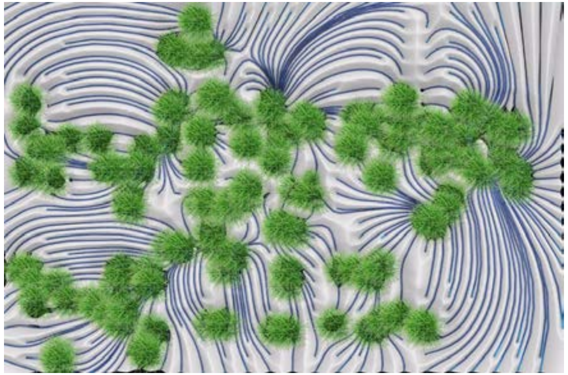
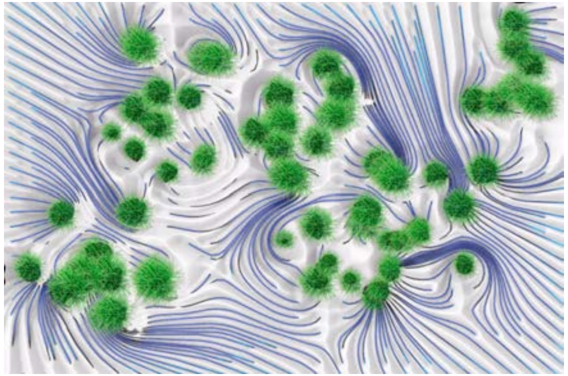
NBS Case Studies: **Food Voltaic**

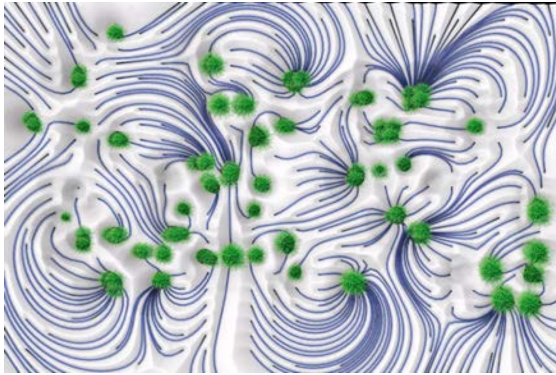
Parametric tools help to easily create the variations for the different scenarios.



Rainy areas:
> More rain
> Less evaporation



> Medium rain
> Medium evaporation



Dry areas:
> Less rain
> More evaporation

NBS Case Studies: **Food Voltaic**

Through an application the systems can be monitored

NBS Case Studies: **FloraVoltaica**

Overview:

The FloraVoltaica project aims to develop a low weight, **flexible façade panel system** that integrates nature into cities, producing and accumulating **bio-photovoltaic energy** and **purifying the air**. These panels, built with photocatalytic materials through 3D printing techniques, include an energy storage system, monitoring sensors, and a management application, from which the user can monitor the health of the plants and the energy production. The panels are design with parametric tools.

For more information: https://advancedarchitecturegroup.net/projects/floravoltaica/

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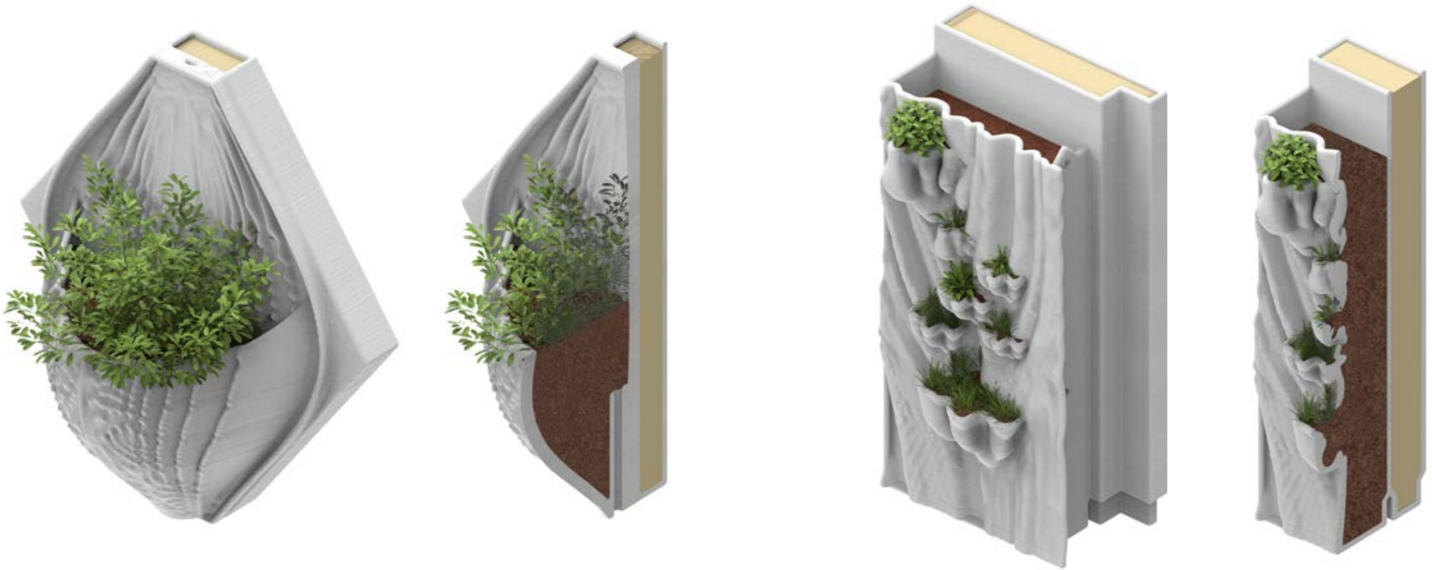
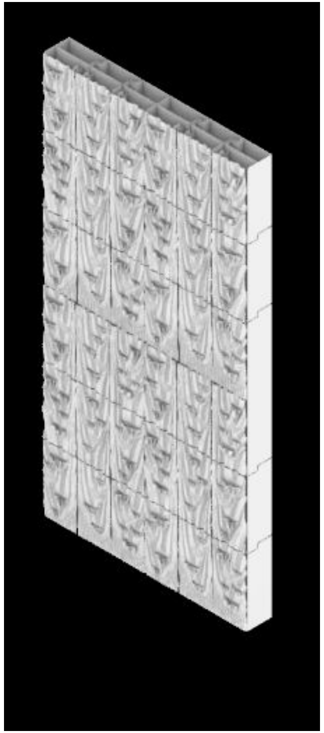
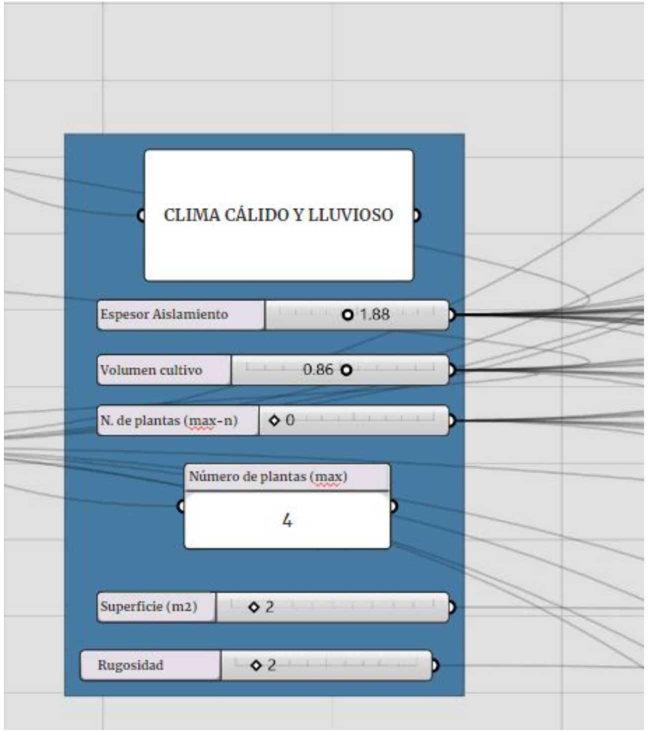
NBS Case Studies: **FloraVoltaica**



NBS Case Studies: **FloraVoltaica**





Parametric Tool Inputs & Outputs

INPUTS

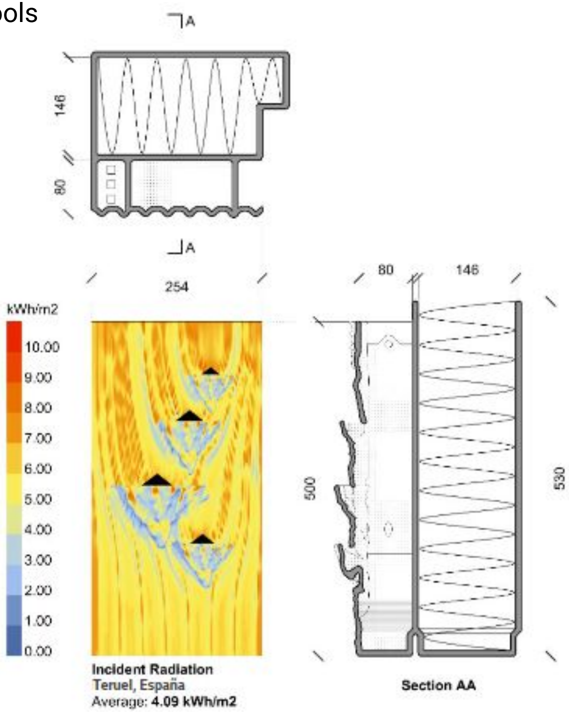
- Insulation thickness
- Cultivation volume
- Number of plants
- Surface of façade
- Roughness of pattern

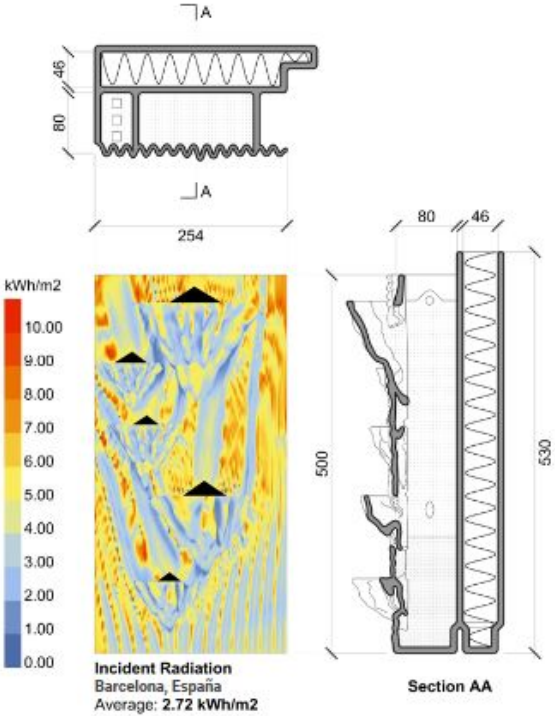
OUTPUTS

- Optimal Climate
- Maximum N. of plants

NBS Case Studies: **FloraVoltaica**

Running analysis with digital tools





SECTION **FOUR**

NBS Case Studies: **Bio-MON**

Overview:

Bio-MON explored the implementation of **phytodepuration** systems for grey water within urban spaces. Not only does the system work to filter water, but it also **produces energy** and oxygen.
Digital fabrication techniques were used to fabricate the modules which houses a series of layers that help to capture the electrons. The design of the modules allows the water to cascade down, filtering the water each time.

For more information
https://www.iaacblog.com/programs/bio-mon/

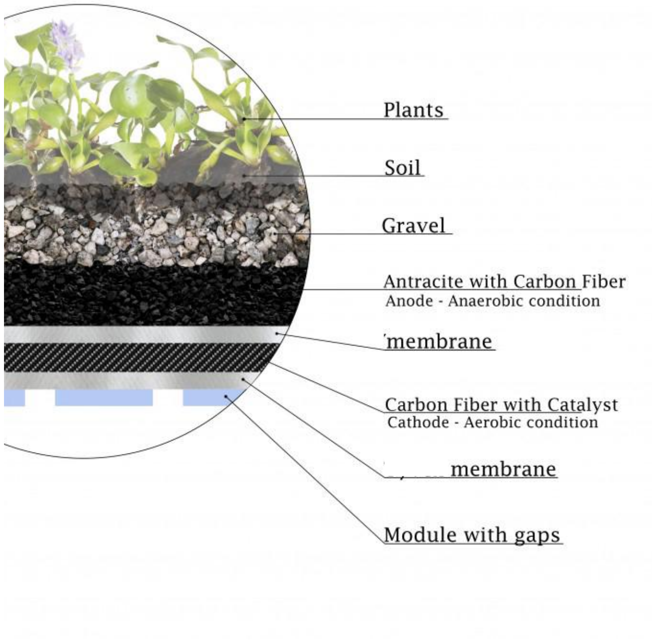

Advanced Architecture Group & MAA 01 - SE.9 - Urban Bio-systems
Students: Maya Mohan, Ozge Tektas, Nusrat Tabassum

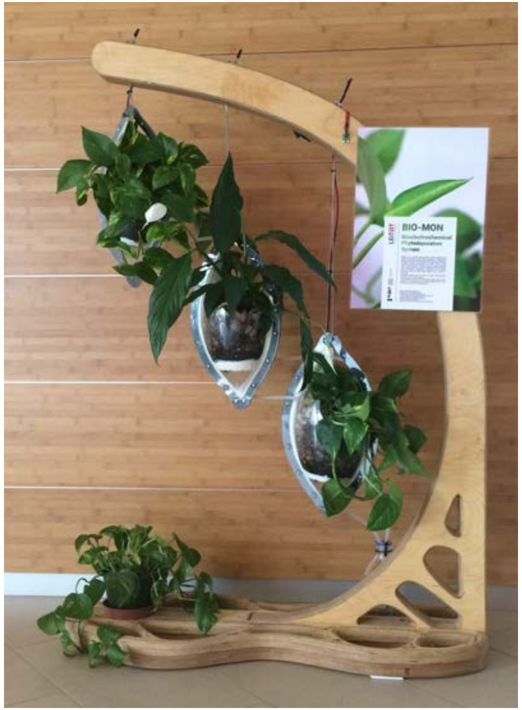
Developed with:

LEITAT Technological Center

SECTION **FOUR**

NBS Case Studies: **BIO-MON**





Advanced Architecture Group & MAA 01 - SE.9 - Urban Bio-systems
Students: Maya Mohan, Ozge Tektas, Nusrat Tabassum

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NBS Case Studies: **RootSkin**

Overview:

RootSkin was designed as a **biodegradable textile** made from plant roots that could be used as a shading device. The patterns are designed through **parametric tools,** and then the molds are digitally fabricated using a **CNC machine.** Seeds are planted on the mold and after a certain amount of time, the roots are harvested from the plants leaving a root textile. Overtime, this biomaterial will disintegrate and return to the soil it was once grown in, providing food for the next cycle of plants.
For more information:
https://revistes.ua.es/uou/article/view/23631/22040


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NBS Case Studies: **RootSkin**

➔ During the RootSkin research, different mold were created to test materials and geometries. At the small scale, moulds were 3d printed and at the larger scale they were cnc milled.

NBS Case Studies: **RootSkin**

NBS Case Studies: **RootSkin**

SECTION
FIVE

Further Reading

Further Reading

Design & NBS:

The role of Nature-Based Solutions in architectural and urban design
Elena Mussinelli, Andrea Tartaglia, Luca Bisongni, Sergio Makcevschi
https://oaj.fupress.net/index.php/techne/article/view/5003/5003

How would Nature design and implement Nature-based Solutions?
Bianciardi, A., Becattini, N. and Cascini, G.
https://doi.org/10.1016/j.nbsj.2022.100047

Building urban resilience with nature-based solutions: How can urban planning contribute?
Judy Bush, Andréanne Doyon
https://www.sciencedirect.com/science/article/pii/S0264275119313976

Further Reading

TED Talks:

How to transform sinking cities into landscapes that fight floods
Kotchakorn Voraakhom
https://www.ted.com/talks/kotchakorn_voraakhom_how_to_transform_sinking_cities_into_landscapes_that_fight_floods?language=en

Using nature's genius in architecture
Michael Pawlyn
https://www.ted.com/talks/michael_pawlyn_using_nature_s_genius_in_architecture/transcript?language=en

Design at the intersection of technology & biology
Neri Oxman
https://www.ted.com/talks/neri_oxman_design_at_the_intersection_of_technology_and_biology?language=en

SECTION
SIX

References

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