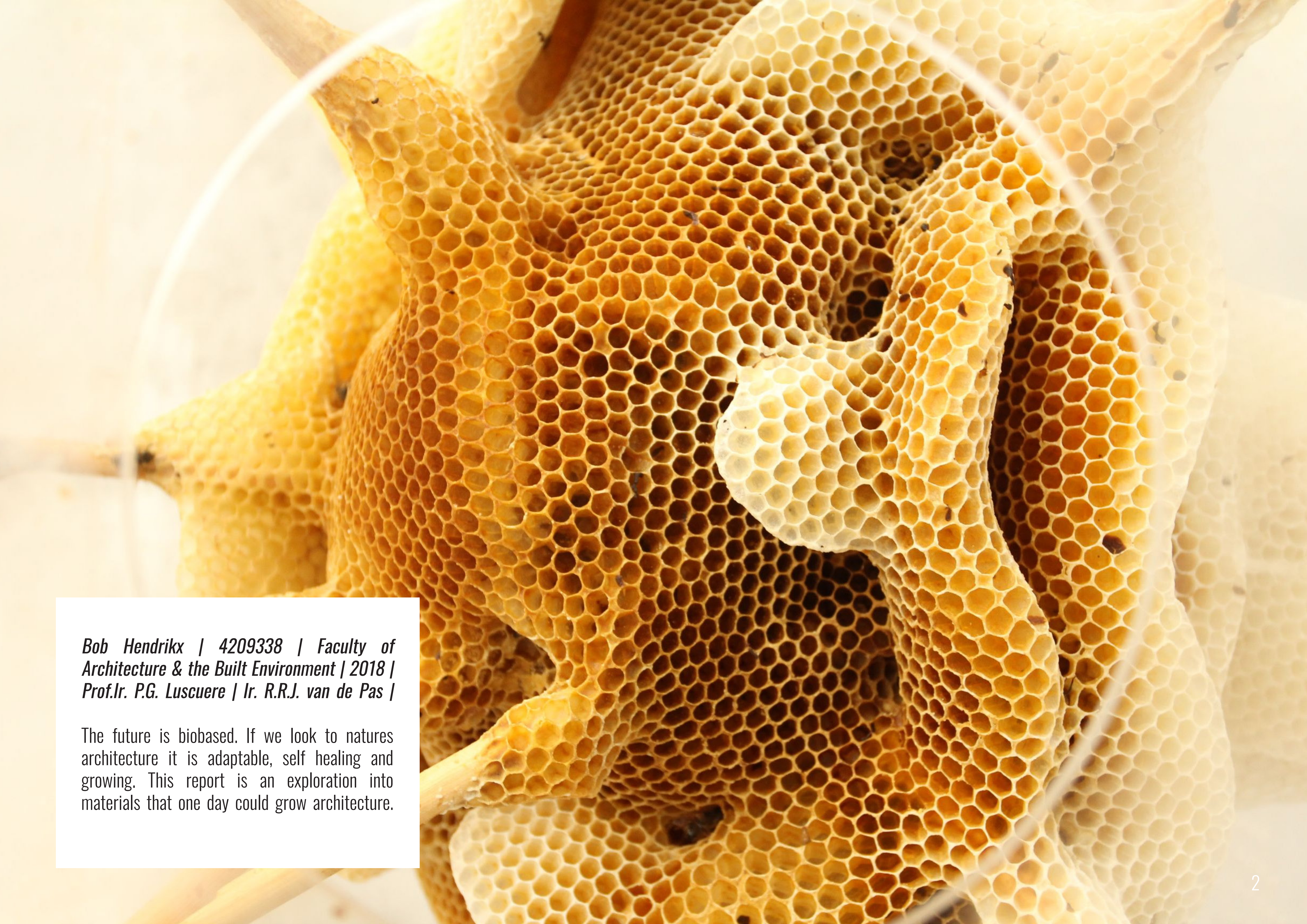
EIGHT PROMISING MATERIALS TO GROW ARCHITECTURE



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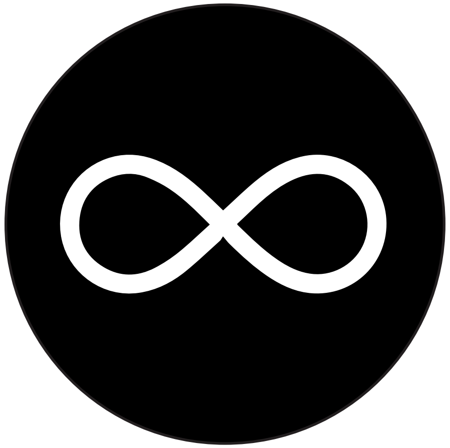
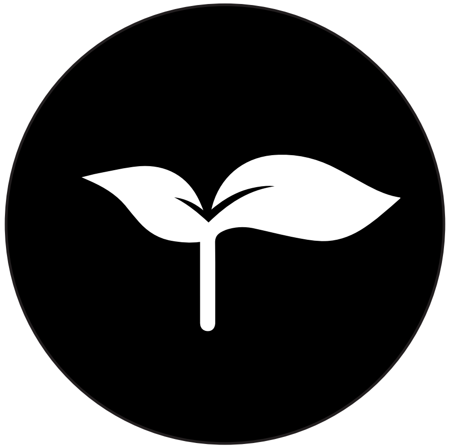
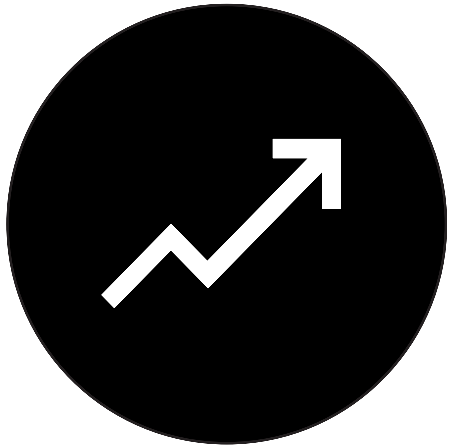
The future is biobased. If we look to natures architecture it is adaptable, self healing and growing. This report is an exploration into materials that one day could grow architecture.



Renewable



Biobased



Scalable

DEMANDS

ALGAE

+

- Fast growing
- Easy to grow
- CO_2 absorption
- Form freedom
- Lightweight

−

- Never been used in construction
- Soft material
- Could harm marine life

✓

- Biofuel
- Food
- Pharmacy
- Cosmetics

🔍

- 3D printing filament
- Bioplastics
- Facade sheeting
- Green roof/facade
- Algae brick
- Sustainable cement

CO_2 absorption:	Yes
O_2 production:	Yes
Weight:	920 kg/m3[1]
Growth temperature:	5-40C[2]
Growth rate:	200% in 1 day[3]

Among the oldest forms of life on Earth, algae are single-celled organisms that grow in freshwater, seawater and also may grow in damp soil and rocks. They can withstand and grow in both hot and cold waters. Single-celled algae grow by simply dividing themselves into two. Like other plants and organisms, algae use photosynthesis to turn light, carbon dioxide and a few nutrients into the oils, carbohydrates and proteins that make up their cell structure[4].

Microalgae in particular are among the world's fastest-growing organisms, with some species capable of doubling in volume in just six hours[5]. From an environmental point of view the biggest advance of algae is that they improve air quality and reduce greenhouse gases since it absorbs carbon dioxide and converts it into oxygen. It grows 10 times more rapidly than terrestrial plants, and less than a tenth of the land is needed to produce an equivalent amount of biomass[6]. The growth conditions are minimal since it can grow almost anywhere on the planet (even in polluted water) and double in size within a day. Even in the coldest oceans algae provide the primary source of organic material to animals at the bottom of the food chain with their richness in vitamins, minerals and proteins.

Other than being beneficial for the marine life, excessive amounts of algae is also harmful to them. Due to rapid reproduction, algae sometimes block sunlight from reaching the aquatic plants, which results in their deaths[7]. While certain algae is necessary for a functioning marine ecosystem, other species can be damaging. The hair algae growing in water may cause the death of aquatic animals due to strangulation[8]. Furthermore, a small percentage of algae species naturally produce toxins, which can be harmful to animals that consume them. The toxins sometimes lead to human illness when seafood becomes contaminated. Harmful algal blooms

Bio Intelligent Quotient building | Hamburg, Germany | Arup | Facade | Biofuel | 2013

'Natural, efficient and unique: the BIQ is setting new standards as the first building in the world to have a bioreactor façade. Microalgae are cultivated in the glass elements that make up its "bio skin". These are used to produce energy, and can also control light and provide shade.'[9]

can also cause oxygen depletion in a body of water.

At the moment algae found its way into the sectors of biofuel, food and pharmacy. Most production techniques grow the algae like any other crop. Once harvested, the oil can be extracted and refined into biodiesel, gasoline and even jet fuel. In addition to algae oil, the protein and carbohydrates in algae can are mostly used for food, animal feed, health products and supplements, chemicals, pharmaceuticals and even cosmetics. A latest innovation is to create 3D filament with algae to print a new bioplastic

Algae could make a huge environmental impact if implemented in the built environment due to the carbon adsorptive properties. When thinking of a building material we envision strength and stiffness. Yet algae are blubbery and soft. Research has to be done to conclude if algae could be a potential building material with constructive properties. Research by Studio Klarenbeek resulted in a bioplastic which could potentially be used for facades. While in previous examples the algae were grown and killed for their purpose. An other option would be to keep the algae alive while using it natural characteristic. Algae could be mixed with plaster to achieve a growing facade or could find a way to create a new type of green roofs.

Algae Dome | Art fair Copenhagen, Denmark | Space10 | Pavilion | Food | 2017

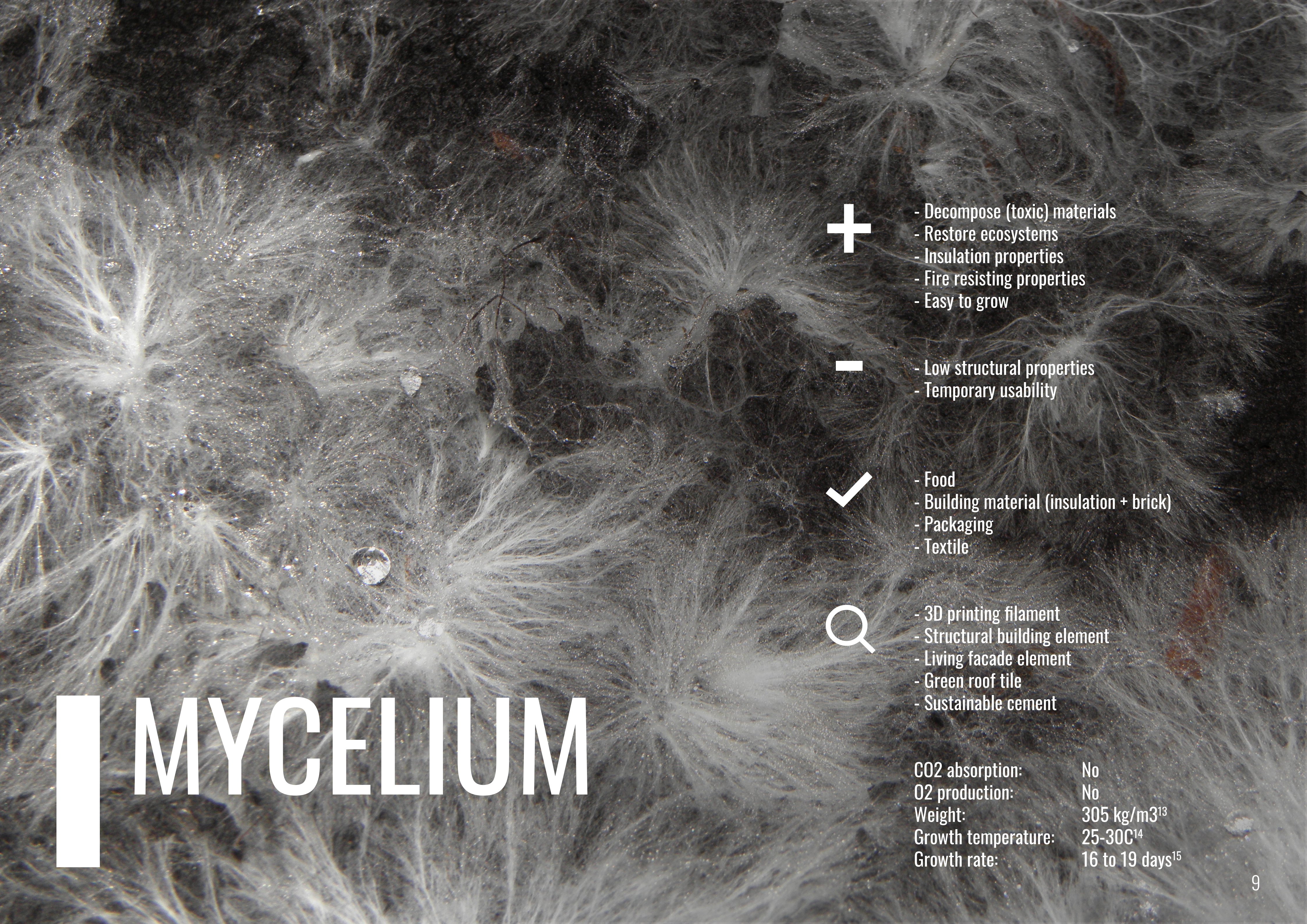
'The Algae Dome is a four-metre-high plywood pavilion housing a photo-bioreactor; a closed-loop system that produces a huge amount of micro-algae. The algae is used to produce food and to create awareness about the CO2 footprint of our current agriculture.'[10]

Biodegradable Algae Water Bottle | Reykjavik, Iceland | Ari Jónsson | Bottle | Bioplastic | 2016

‘When red algae powder is added to water, the resulting jelly-like material is strong enough to be used as a container. Once it has been emptied of liquid, the bottle immediately begins to lose its shape and decompose – a useful feature that enables it to be discarded without damaging the environment.’[11]

3D Algae filament | Zaandam, the Netherlands / Eric Klarenbeek | Pottery | Bioplastic | 2017

'Researching new values for local wetlands as incubators for locally grown bio-materials, the project explores the potential of growing micro- and macro-algae locally. These algae are then mixed with biopolymers that can replace non-biodegradable, fossil oil-based plastics and simultaneously absorb carbon dioxide emissions.'[12]



MYCELIUM

+

- Decompose (toxic) materials
- Restore ecosystems
- Insulation properties
- Fire resisting properties
- Easy to grow

−

- Low structural properties
- Temporary usability

✓

- Food
- Building material (insulation + brick)
- Packaging
- Textile

🔍

- 3D printing filament
- Structural building element
- Living facade element
- Green roof tile
- Sustainable cement

CO_2 absorption:	No
O_2 production:	No
Weight:	305 kg/m3[13]
Growth temperature:	25-30C[14]
Growth rate:	16 to 19 days[15]

Mycelium is the internet of nature. A mycelium is the vegetative part of a fungus, and is made up of white or cream colored fungal threads or filaments that are known as hyphae. The size of a single mycelium ranges from being very minuscule to being as widespread as a forest. The branching mycelium masses, typically found underground, can form a massive network. More than 13 km of hyphal filaments can sometimes be found in one cubic inch (2.54 cubic centimeters) of soil. The mushroom is only the fruiting body of this creature though. It's sole purpose is to explode from the ground, spread their caps, and throw millions and millions of spores into the air to reproduce. Then they mature, start to rot and decompose back into the soil from where it came[17].

Mycelia are highly important to the ecosystem as they help to decompose organic material. Acting as biological filters, they have the ability to eradicate pollutants like petroleum products and pesticides[18]. When mycelium is decomposing materials, nutrients are released into the surrounding soil or water. These required nutrients are taken up by the roots of plants to enable growth[19]. When dried, mycelium can be used as a robust substance to construct everyday products and building material, for example. The material can withstand extreme temperatures and is water, fire and mould-resistant[20].

On the other hand, we have always to keep in mind that mycelium materials are natural materials and therefore are perishable and temporary, they are subjected to decay and to degradation. Of course, the durability and performance of the material in regards to certain aspects can be adjusted by making some compromises that are not always ideal. In such case, one may have to introduce materials that are not natural – or not fully natural – so to provide certain properties that are not

Biodegradable wine package | New York, USA | Ecovative design | Packaging | Mycelium | 2008

'Ecovative is the pioneer and world leader in the design and manufacturing of mycelium-based biomaterials. With pattented technologies they mostly produce packaging for large corporations and insulation and foams for the building sector. Their latest innovation is the self 'grown' tiny house.'[16]

natural – or not fully natural – so to provide certain properties that are not embedded in the mycelium itself. This is partly a need for current industrial and market requirements, though could also be seen as a cultural disadvantage, in the sense that we believe that things should last forever whereas these materials suggest that things should be temporary, as everything that exists is temporary[22].

Mycelium has found its way into the sectors of food, building material, packaging, textile and medicine. World wide mycelium is cultivated to produced mushrooms for food. In the building industrie mycelium is grown with agricultural waste which delivers a good insulation material. Architect David Benjamin even build a pavilion with by creating a mycelium brick. Some companies like Ecovative are using the material to ship packicking since the materials has shock adaptive properties. In the textile industry a new kind of leather is grown rapidly from mycelium and agricultural byproducts in a carbon-negative process.

According to Paul Stamets, mycelium is going to save our lives and restore earths damaged ecosystem. The promising material is a potential constructive building material if the structural properties improve. This could be done by experimenting with new additives to the process or implementing structural reinforcement. A yet more closeby potential is a facade element, that would have insulating properties and would also benefit diversity since plants and insects could settle on the exterior. To have a more financial accessible and lightweight green roof alternative mycelium could also be a solution. In all options mentioned above a great process innovator would be to insert the mycelium substance into a 3D printer. In this situation we would realise a decentralised biobased production, which could revolutionize the way we build.

Myceliumchair | Zaandam, the Netherlands | Eric Klarenbeek | Chair | 3D printing | 2013

'Studio Klarenbeek and Dros are exploring ways of 3D-printing living organisms, such as mycelium, the threadlike network of fungi, in combination with local raw materials to create products with a negative carbon footprint.'[21]

Hy-fi / New York, USA | The Living & Ecovative | Pavilion | Brick | 2014

'In the courtyard of MoMA's contemporary art space, a cylindrical tower soars 40 feet into the air. The twisted brick chimney looks like it's made from bricks, and it is. Only these bricks aren't cast in clay—they're made from a combination of chopped up corn stalks and mycelium, the root of fungus.'[23]

MycoTree | Seoul, South Korea | Hebel & Block | Load bearing | Construction | 2017

'MycoTree is a naturally-grown spatial branching structure comprising load-bearing mycelium components and bamboo. It has been developed for the Seoul Biennale for Architecture and Urbanism in response to the need for new and alternative materials and approaches to construction.'[24]

BIOBRICK

- No need for energy
- Made in ambient temperatures
- No CO2 emissions
- Can be made on site
- No waste in manufacturing

- Highly stable production environment
- Toxic by products
- Slow growth

- Biobrick
- Furniture

- Sustainable cement
- 3D printing filament
- Facade elements

CO2 absorption:	No
O2 production:	No
Weight:	1400 kg/m3[25]
Growth temperature:	Ambient temperature[26]
Growth rate:	1 brick takes 1-2 weeks[27]

The BioBrick utilizes a natural process found in common bacteria to fuse sand particles and thereby create a rigid shape with strength and durability comparable to those of conventional bricks. The scientist combines the microorganisms with sand and a solution of calcium chloride and urea to initiate microbial-induced calcite precipitation, whereby the bacteria glue the grains of the sand together to form stone[28].

The brick is a ubiquitous and effective construction component that has endured for thousands of years relatively unchanged. It is inherently simple and it is both durable and sized to fit the human hand. But while its form and function have been mastered, its standard method of production is damaging: intense heat energy, with a requirement for large quantities of agricultural soil, leaves a significant ecological footprint.The biobrick therefor is a more sustainable solution to an existing product.

As with all life processes, this one is sensitive to environmental conditions and it is not yet mastered for the demanding pace of industry. Factors such as temperature, density of nutrients and pH levels must all be maintained within particular ranges for it to work and it can take a full week to form. Another challenge of biologically grown bricks is their toxic by product: ammonia. Production on large scale would require supplementary process to contend with this potentially dangerous gas[29].

In 2010 Ginger Krieg Dosier developed a technique for using microbiologically induced calcite precipitation to manufacture bricks for construction. After winning several competitions she founded bioMASON, which focuses fully on a new biobrick. Various other designers are now experimenting to copy the natural process of construction of sea shells.

Biobrick | North Carolina, USA | bioMASON | Sand & Bacteria | Prototype | 2010

'BioMASON is a unique biotechnology start-up company with a natural process that is revolutionizing the building and construction industry. They employ microorganisms and chemical processes to manufacture biological cement-based masonry building materials in ambient temperatures.'[30]

Biobrick | Cape Town, South-Africa | Dyllon Randall | Sand & Bacteria | Prototype | 2018

'Human urine has been used to create environmentally friendly bricks by university students. They combined urine with sand and bacteria in a process that allows the bricks to solidify at room temperature. "It's essentially the same way that coral is made in the ocean," Dyllon Randall, their supervisor at the University of Cape Town.'[31]

Dupe | Edinburgh, Ireland | Peter Trimble | Sand & Bacteria | Chair | 2014

'Edinburgh College of Art student Peter Trimble has built a portable machine for manufacturing furniture from sand, urine and bacteria. As part of his thesis project, Peter Trimble explored how bacteria and the urea found in urine might be used to create a reusable material that requires fewer resources than conventional concrete.'[32]

BIORECEPTIVE CONCRETE

+
- Enhancing biodiversity
- Clean air
- No maintenance
- No soil
- No irrigation

−
- Slow growth
- Early stage technology
- Exterior usage

✓
- Facade panel

🔍
- Roof tile
- Exterior walls
- Infrastructure
- Stamp for wet concrete

CO_2 absorption:	Yes
O_2 production:	Yes
Weight:	2400 kg/m3[33]
Growth temperature:	Ambient temperature
Growth rate:	1 year[34]

In 2015 the BiotAlab at the Bartlett School of Architecture, University College London created a bioreceptive concrete that enables the hosting of microorganisms and nurtures biocolonization. The organisms growing in the concrete produce oxygen and absorb CO2 and pollution[35].

Bio-concrete will allow plant life to thrive on buildings in a way that is both more sustainable and more efficient than existing green walls. Importantly, it will do so without compromising the structural integrity of our built environment[36]. The lab has successfully developed a magnesium phosphate-based concrete that is capable of hosting microorganisms and nurturing bio-colonisation directly from the pores on its surface, without the need for soil and associated irrigation systems[37].

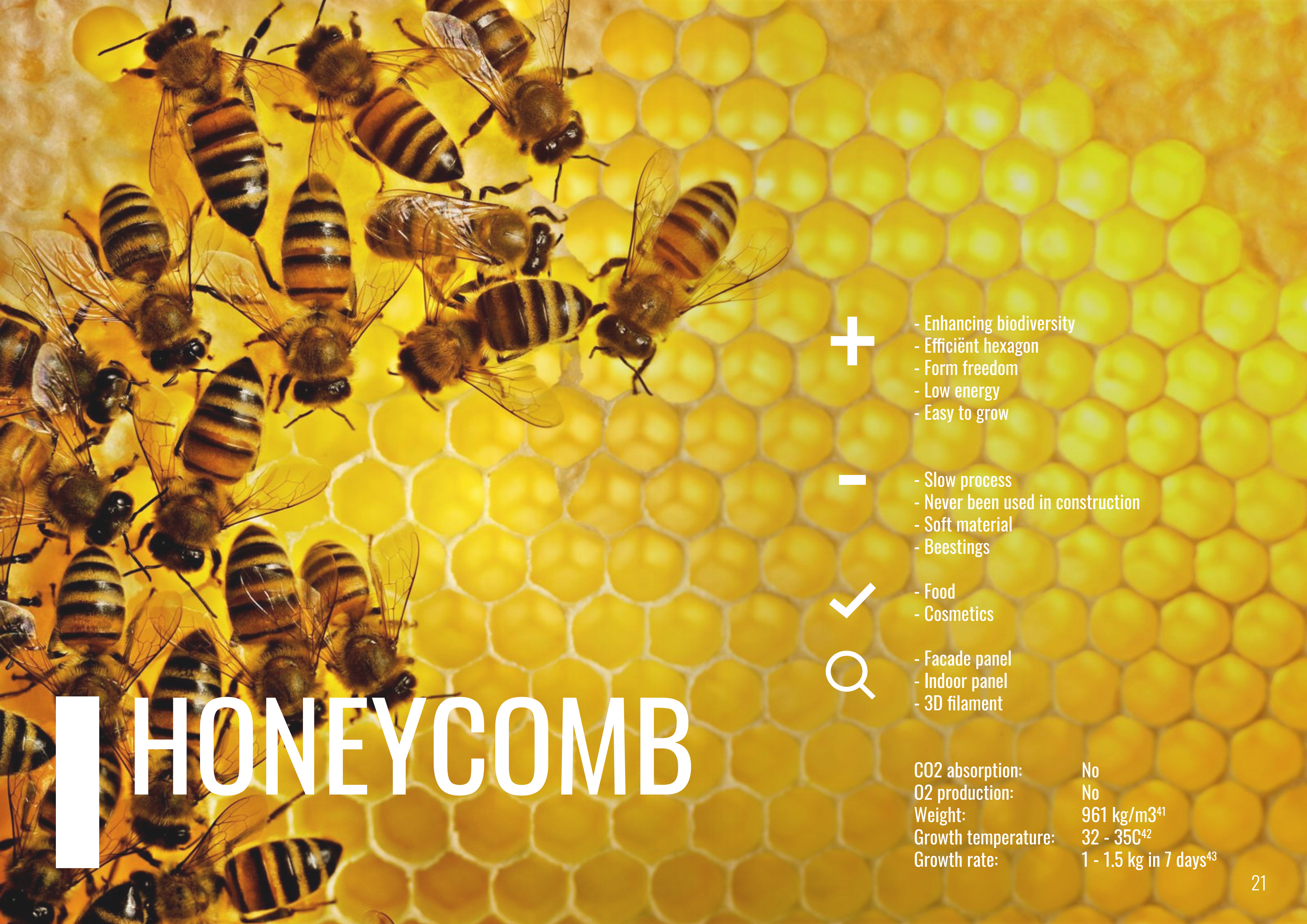
In theory the materials sounds promising but only one party has started actual prototyping, so the technology is yet in an early stage. It is still unknown how the materials is keeping its default properties after the growing process of the microorganism will start after 1 year. Research into the ground-breaking construction material is an interdisciplinary practice that brings together architecture, biology and engineering. The aim – which has already been achieved by a small handful of people – is to develop a wall-panel system capable of growing micro-organisms directly on its surface. It is envisioned that these bioreceptive panels could be applied over a range of urban contexts with a particular opportunity for infrastructural projects, including large-scale retaining walls, elevated railway lines and embankment walls, as well as furniture and pavements in public spaces. This can also be applied to buildings ranging in scale and typology from individual houses or housing blocks to the many blank and rather 'wasted' building façades of larger buildings[38].

Bioreceptive concrete | London, United Kingdom / BiotA Lab | Facade panel | Prototype | 2015

'The facades are being designed and tested as innovative wall-panel systems capable of enhancing bio-colonization of building facades. By utilizing novel design and digital fabrication methods, surface morphology and roughness are enhanced to improve the facade performance through the implementation of a new type of biologically receptive concrete.'[39]

Bioreceptive concrete | London, United Kingdom | BiotA Lab | Facade panel | Experiment | 2015

'Magnesium phosphate is combined with Portland cement into different geometries to promote the growth of mosses, lichens and algae in different areas of the concrete. The plants are able to produce oxygen, and filter or absorb CO_2 and other contaminants in the air. This system creates something similar to a green wall without the expense and maintenance.'[40]



HONEYCOMB

+
- Enhancing biodiversity
- Efficiënt hexagon
- Form freedom
- Low energy
- Easy to grow

−
- Slow process
- Never been used in construction
- Soft material
- Beestings

✓
- Food
- Cosmetics

🔍
- Facade panel
- Indoor panel
- 3D filament

CO_2 absorption:	No
O_2 production:	No
Weight:	961 kg/m3[41]
Growth temperature:	32 - 35C[42]
Growth rate:	1 - 1.5 kg in 7 days[43]

A honeycomb is a mass of hexagonal prismatic wax cells built by honey bees in their nests to contain their larvae and stores of honey and pollen[44]. When the temperature is right, worker bees secrete wax scales from special glands in their body. Then they chew the wax with a bit of honey and pollen to produce the beeswax. The hexagonal cells serve as storage vessels for honey, as well as homes to raise young bees[45]. Creating beeswax is a fairly expensive process for the bee, as they consume eight ounces of honey for every one ounce of wax they create. To work as efficient as possible bee's developed a hexagonal shape, which by mathematicians is the best way to divide a surface into regions of equal area with the least total perimeter. The conjecture was proven in 1999 by mathematician Thomas C. Hales[46].

Bees can be extremely intelligent. Not only do they learn how to overcome obstacles by doing, but they can actually learn by watching others as well. Bees are also brilliant mathematicians. Bees perform a waggle dance which utilizes speed and directionality to communicate the location of resources relative to their current position and the Sun. Over their evolutionary history, they have mastered the art of storing the most amount of honey while using the least amount of resources. The process of creating structures is completely natural, low energy and low temperatures and it deliberately uses a species that is important in agriculture and threatened by changes in the environment[47].

The process of manufacturing is slow. For example, the vases produced by Tomás Libertiny was the results of 40.000 bees working for 1 week. Although extremely beneficial to crops, health, and making useful natural products for the body and home, the main disadvantage of working with honeybees is their painful stings. Fortunately, they only sting when they feel threatened.

The Agreement | London, United Kingdom | Tomás Libertiny | Sculpture | Art | 2012

'Studio Libertiny designed an organic tower-like structure on which the bees were invited to build their home (wax honeycombs). The skeleton was carefully engineered to accommodate for tensions and stability as well as minimal obstruction for building of cells.' [48]

Because their stingers are barbed, they often remain inside the skin, releasing more venom and causing more pain. Nowadays we use bees for the food and cosmetics. Artist have begun experimenting with using bees a 3D printing tool. While there is no direct implementation of bees in a building material, their wisdom of the hexagonal structure is widely used in construction.

A potential use for honeycomb would be for example exterior facade panels where microorganisme could settle, or even bees could continue their waxing process. With the technique which artist are using to create a honeycomb in a form of choice a lot of freedom is created. Realistically honeycomb could find its way into a more decorative purpose. Yet more research has to be done on structural properties to conclude if it could also be a used as a constructive building material.

Yuansu II | Beijing, China| Ren Ri | Sculpture | Beeswax | 2013

'The artist first builds transparent polyhedrons and cubes with an inner framework of wooden dowels, at the center of which he places the queen. After introducing the rest of the hive, he then rotates the sculpture every seventh day based on the roll of a die, an act that he says references the biblical concept of creation.'[49]

SILKWORM

+
- Enhancing biodiversity
- Efficiënt hexagon
- Form freedom
- Low energy
- Easy to grow

−
- Slow process
- Never been used in construction
- Soft material
- Beestings

✓
- Food
- Cosmetics

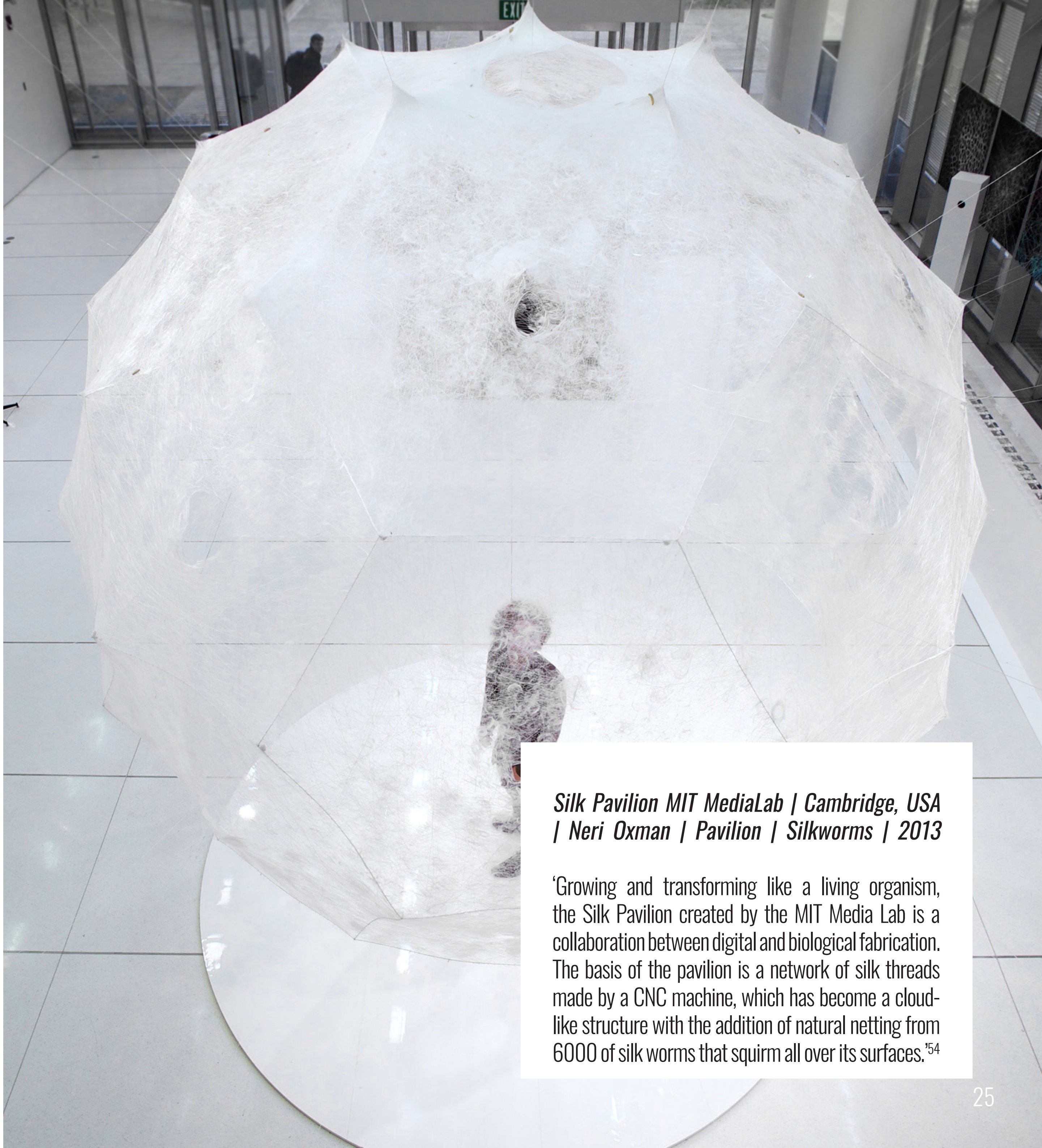
🔍
- Facade panel
- Indoor panel
- 3D filament

CO2 absorption:	No
O2 production:	No
Weight:	250-450 kg/m3[50]
Growth temperature:	25C[51]
Growth rate:	433m per day per worm[52]

The silkworm is the larva or caterpillar of the domestic silkmoth. It is an economically important insect, being a primary producer of silk. Silk is a natural protein fiber, some forms of which can be woven into textiles. Domestic silk moths are closely dependent on humans for reproduction, as a result of millennia of selective breeding. The practice of breeding silkworms for the production of raw silk, has been under way for at least 5,000 years in China. Wild silk moths are different from their domestic cousins as they have not been selectively bred; they are not as commercially viable in the production of silk. The silk worms are not the only insect producing silk. Silk is mainly produced by the larvae of insects undergoing complete metamorphosis, but some insects such as webspinners and raspy crickets produce silk throughout their lives.

The flat surfaces of the fibrils reflect light at many angles, giving silk a natural sheen. Silk is one of the strongest natural fibers, but it loses up to 20% of its strength when wet. Its elasticity is moderate to poor: if elongated even a small amount, it remains stretched. It can be weakened if exposed to too much sunlight. Silk is a poor conductor of electricity and thus susceptible to static cling. Silk has a high emissivity for infrared light, making it feel cool to the touch[53]. Non-organic silk is often unethically obtained. Silkworms or silk-producing moths are sometimes harmed or killed during the collection of their silk cocoons. Silk cocoons are collected before the worm reaches maturity and this interferes with its life cycle. Organic silk or wild silk is animal-friendly and is collected ethically.

Silk is a material that is embedded for many years into our culture. The material is used mostly in the sectors of textile, furniture, industry, medicine. Silk's absorbency makes it comfortable to wear in warm weather and while active. Its low conductivity keeps warm air close to the skin during



Silk Pavilion MIT MediaLab | Cambridge, USA | Neri Oxman | Pavilion | Silkworms | 2013

'Growing and transforming like a living organism, the Silk Pavilion created by the MIT Media Lab is a collaboration between digital and biological fabrication. The basis of the pavilion is a network of silk threads made by a CNC machine, which has become a cloud-like structure with the addition of natural netting from 6000 of silk worms that squirm all over its surfaces.'[54]

cold weather. Silk's attractive lustre and drape makes it suitable for many furnishing applications. Silk had many industrial and commercial uses, such as in parachutes, bicycle tires, comforter filling and artillery gunpowder bags.

The material is only one time used in an architectural purpose. The Silk Pavilion by Neri Oxman explores the relationship between digital and biological fabrication on product and architectural scales.The primary structure was created of 26 polygonal panels made of silk threads laid down by a CNC (Computer-Numerically Controlled) machine. Since silk is not perfectly weather resistant a purpose for indoor would suit better. It could function as separation walls, sunblocker, 3D filament or temporary structures.

Purity of Silk | Eindhoven, The Netherlands | Iris Seuren | Clothing | Silkworms | 2018

'Silkworms create a blouse by weaving their threads across a special frame, in blissful ignorance of the problems facing the clothing industry. The domesticated silkworms, living their lives in an artificial environment, rely on human care. Mankind on the other hand, is totally dependent on the worms to produce valuable silk.'[55]

CRYSTALS

+

- Easy grow process
- Low energy
- Structural properties
- Translucent properties
- Good insulators

−

- Slow growth
- Salt dissolves in water
- Poor toughness
- Heavy

✓

- Jewelry
- Industrie
- Chemistry
- Anthropology

- Structural material
- Facade panels
- Crystal tiles
- Crystal brick

CO2 absorption:	No
O2 production:	No
Weight:	2165 - 3539 kg/m3[56]
Growth temperature:	The warmer the faster[57]
Growth rate:	Differs per type

A crystal is a solid material caused by a natural process called crystallization. When liquids cool or harden, atoms and molecules bound together in a uniform and repeating pattern in their search for stability. This pattern causes the material to grow in various unique shapes. In nature the process of crystallization occurs when for example, magma cools or salt water evaporates. Crystallization is a process that occurs in nature. From snowflakes and stalactites to honey, the process is low energy and relatively easy to manipulate by humans. In comparison to glass, crystal has special electrical, optical and mechanical properties. The material properties per crystel differ since there are so many different types. The common knowledge about these materials is that they are hard, conduct energy when fluid and are good insulators. For example, diamonds are the hardest natural occurring material in the world. From an architectural point of view, the translucency of the material could result in interesting new compositions[59].

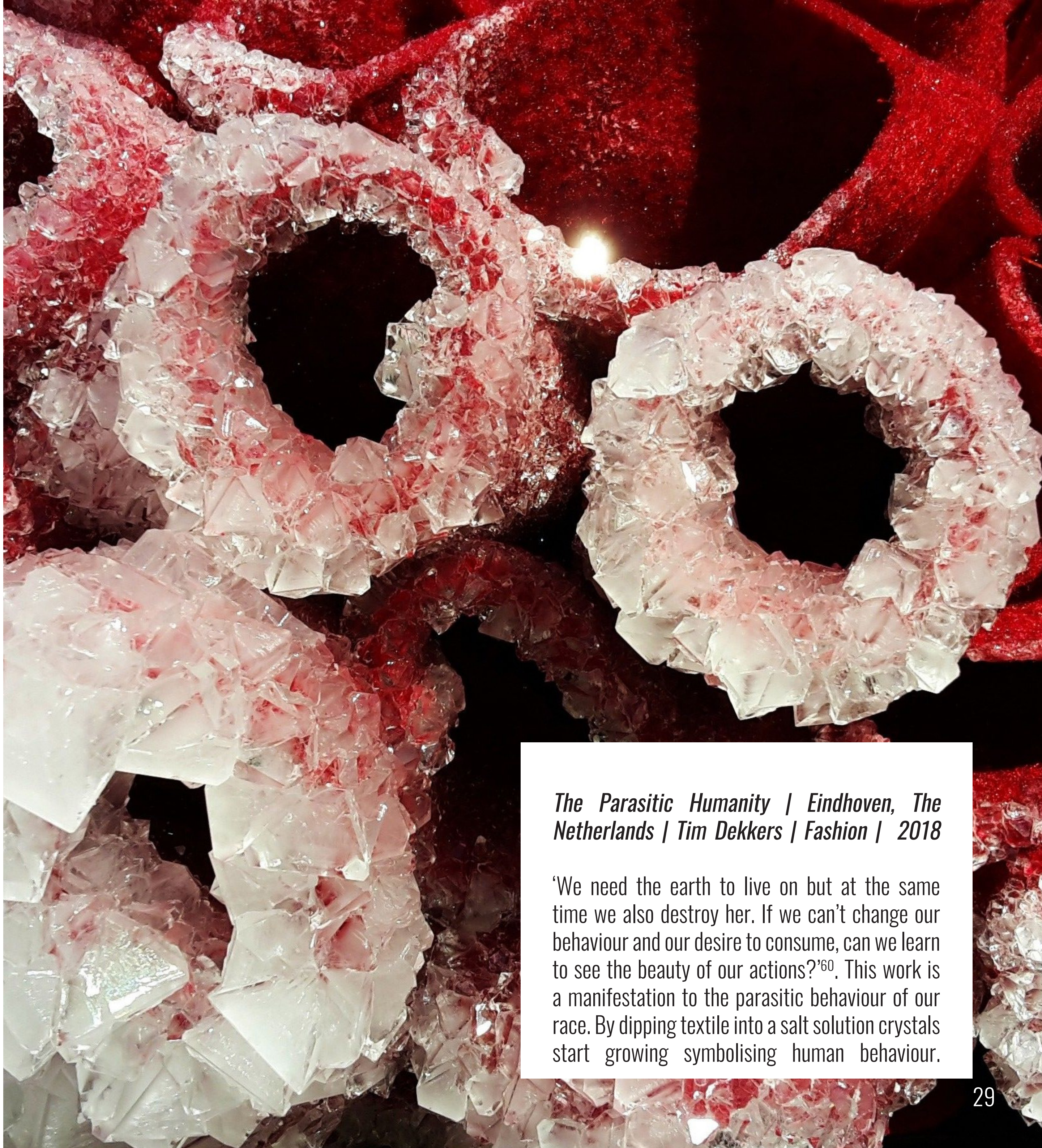
Unlike hardness, most crystals are vulnerable to breakage. For example, a diamond will shatter in small pieces if confronted with impact. It is difficult to measure material properties of crystals since the formed layers within the crystal each have their own unique set of properties. The growth process of crystal varies per type. Some grow two centimeters in ten million years where salt for example needs months. To use salt as a building material a disadvantage would be that it dissolves when confronted with water.

Crystals is mostly known for their purpose in the sectors of jewelry of decoration. But it also has a great industrial purposes. The process of crystallization is used throughout nearly all process industries as production, purification or recovery of solid materials. Diamonds are for example, used for industrial saws to cut through stone due to their

Spider's Thread | Tokyo, Japan | Tokujin Yoshioka | Chair | Minerals | 2013

'Tokujin Yoshioka created the Spider's Thread sculpture of a chair by suspending just seven filaments within a frame that was sat in a pool of mineral solution. The solution was drawn up the threads and gradually formed into crystals around them, fleshing out into the shape of a piece of furniture'.[58]

high thermal conductivity. Quartz is one of the most used crystals in the watch business due to its scratch resistance and it is also used to create silicon metal which is used in the chip industrie[61]. The potential use for crystals in the build environment is large due to its constructive, reflective and translucent properties. A project by Eric Geboers explored the usage of salt in construction resulting in a new archetype.



The Parasitic Humanity | Eindhoven, The Netherlands | Tim Dekkers | Fashion | 2018

'We need the earth to live on but at the same time we also destroy her. If we can't change our behaviour and our desire to consume, can we learn to see the beauty of our actions?'[60]. This work is a manifestation to the parasitic behaviour of our race. By dipping textile into a salt solution crystals start growing symbolising human behaviour.

The Salt Project | Rotterdam, The Netherlands | Eric Geboers | Vision | Salt | 2013

'This project is a biomimetic attempt to utilize locally available resources in order to create a scalable solution to combat desertification. With help of the sun, salt is generated, turned into a building material and used for construction, creating a 'closed ecosystem' with no waste'.[62]

WOOD

+

- Easy grow process
- Low energy
- Structural properties
- Natural Insulation
- Relatively lightweight

−

- Slow growth
- Burning
- Durability

✓

- Fuel
- Construction
- Furniture
- Arts

- Living structure
- Faster growing process
- 3D filament

CO2 absorption:	Yes
O2 production:	Yes
Weight:	160 - 1355 kg/m3[63]
Growth temperature:	Differs per wood type
Growth rate:	1cm takes 15 min - 15 jr [64]

Wood is a material produced by trees. It is a porous and fibrous structural tissue found in the stems and roots of trees. The organic material is a composite of cellulose fibers with strong tension capacity, lignin that is resistant to compression and hemicellulose[65]. Since our appearance on earth we have utilized wood as our main raw material. Due to the development of new materials such as steel, plastic and concrete wood was relatively less used during the industrial period. But now that the environmental impacts of that time are widely known, wood has become more popular.

Wood is a renewable and relatively light material with structural, sound and thermal insulating properties. In comparison to other existing building methods wood has a smaller carbon footprint due to the relatively low energy production process. and the carbon absorption from the atmosphere during the growing process.

Wood has also some disadvantages. Since wood is naturally grown material the properties are not consistent throughout the material; the material is anisotropic which is a difference in mechanical and structural properties when measured along different axes; wood is able to shrink and swell; wood is hygroscopic, which means it absorbs moisture from the air.

Wood is mostly used as fuel and construction material. Back in the days it was the main source of fuel, nowadays it is often used in more rural areas. In construction wood is implemented as unprocessed wood or as timber, which means it is processed for industrial construction. In order to gain better material properties wood is sometimes also engineered. Furthermore wood is used in furniture, arts, sports and many more.

Baubotanik Tower | Wald, Germany | Ferdinand Ludwig | Viewpoint | Silver Willows | 2009

'Baubotanik is a method of construction that utilizes living plants as the load bearing systems in architectural structures. Baubotanik takes advantage of the "constructive intelligence" of plants. At the same time the concept exposes architects to the dynamics and uncontrollability of the natural growth process'.[66]

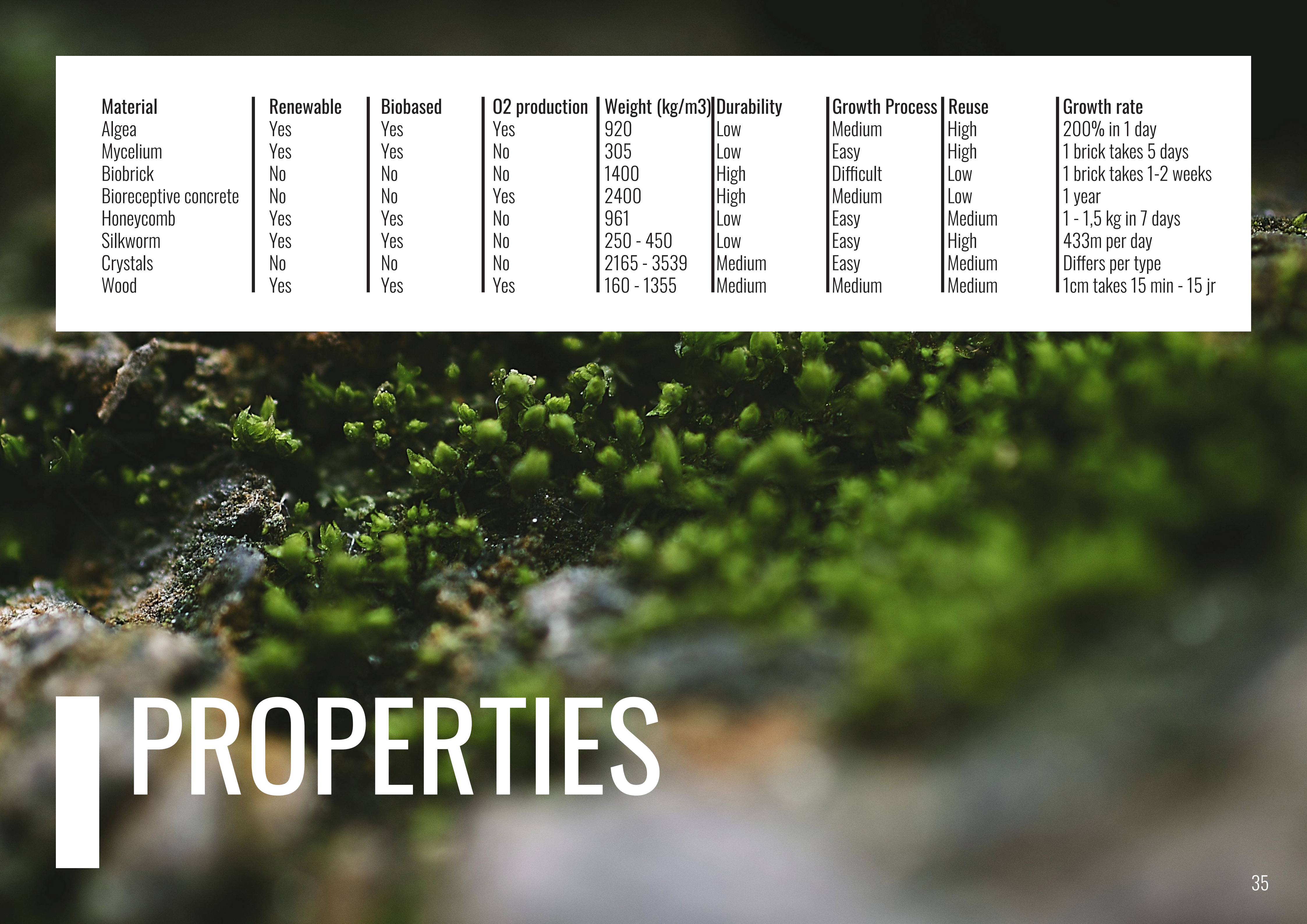
Wood is already engineered in a way that building structural wooden skyscrapers are a reality. Yet wood is not grown locally and the growing and production process is relatively slow. In order to fulfill the markets growing demand and earth's CO2 reduction research has to be done in the field of implementing living trees in construction.

HAUT | Amsterdam, The Netherlands | Team V | Tower | Woodstructure | 2018

HAUT is a 73 metre high residential tower located in the Amstelkwartier. The supporting structure of the Dutch tallest wooden building is mostly build with sustainable European softwood, rather than concrete. It is the first tower in The Netherlands to receive a BREEAM Outstanding label.'[67]

Root Bridges of Meghalaya | Meghalaya, India | Locals | Bridge | Rubber Tree | 1844

‘Throughout the Indian state Meghalay, several examples of rootbridges are found which are formed by the hands of local communities from the aerial roots of rubber fig trees. The bridges come in wide variety. The longstest bridge spans over more than 50 meters.’[68]



Material	Renewable	Biobased	O2 production	Weight (kg/m3)	Durability	Growth Process	Reuse	Growth rate
Algea	Yes	Yes	Yes	920	Low	Medium	High	200% in 1 day
Mycelium	Yes	Yes	No	305	Low	Easy	High	1 brick takes 5 days
Biobrick	No	No	No	1400	High	Difficult	Low	1 brick takes 1-2 weeks
Bioreceptive concrete	No	No	Yes	2400	High	Medium	Low	1 year
Honeycomb	Yes	Yes	No	961	Low	Easy	Medium	1 - 1,5 kg in 7 days
Silkworm	Yes	Yes	No	250 - 450	Low	Easy	High	433m per day
Crystals	No	No	No	2165 - 3539	Medium	Easy	Medium	Differs per type
Wood	Yes	Yes	Yes	160 - 1355	Medium	Medium	Medium	1cm takes 15 min - 15 jr

PROPERTIES

	Structural				*Exterior*		*Interoir*	
Material	**Load bearing**	**Brick**	**3D filament**	**Cement**	**Facade panel**	**Green roof**	**Indoor panel**	**Insulation**
Algea	In potential	In potential	Yes	In potential	In potential	Yes	Yes	Yes
Mycelium	In potential	Yes	Yes	In potential	In potential	Yes	Yes	Yes
Biobrick	Yes	Yes	In potential	Yes	Yes	No	No	No
Bioreceptive concrete	Yes	Yes	In potential	Yes	Yes	Yes	No	No
Honeycomb	In potential	In potential	In potential	In potential	In potential	No	Yes	In potential
Silkworm	In potential	In potential	In potential	In potential	No	No	Yes	In potential
Crystals	Yes	Yes	In potential	Yes	No	No	No	No
Wood	Yes	Yes	In potential	In potential	Yes	No	Yes	Yes

POTENTIAL

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