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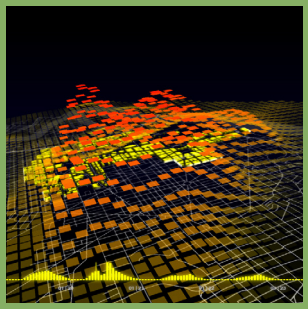

DESIGN FOR SMART CITIES

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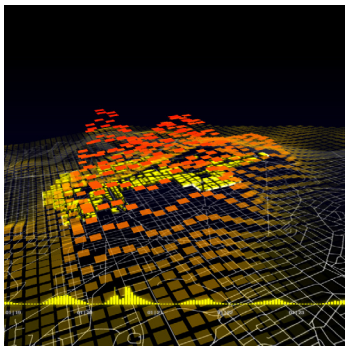

DESIGN FOR SMART CITIES

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DESIGN FOR SMART CITIES

In copertina
"Obama, One People", autori Carlo Ratti, Senseable City MIT, © Proprietari dell'immagine, fonte: http://senseable.mit.edu/obama/index.html

AURA
“Green & Smart Urban Furniture”

Integration of urban furniture IoT and phytoremediation

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Nella prospettiva delle *smart city*, cresce l'interesse per una nuova integrazione tra componenti artificiali e naturali per affrontare le problematiche ambientali. Questo paper [1] intende evidenziare l'approccio perseguito dalla ricerca AURA, un progetto in corso che si basa sull'utilizzo di biofiltri (*Nature Based Solution*) associati a sensori per il monitoraggio ambientale (*Internet of Things*), inseriti in elementi modulari industrializzati per una nuova generazione di arredo urbano. Pertanto, il progetto AURA mira a contribuire allo sviluppo di una vera e propria democrazia digitale, basata sulla condivisione dei dati ambientali e sul coinvolgimento della comunità, rappresentando un tipico processo di innovazione guidato dal design applicato sia all'ambito della tecno-scienza che dell'innovazione sociale.

Riscaldamento Globale, Condivisione Dati, Nature-Based Solutions, Connettività Ambientale, Smart Cities

In the perspective of smart cities, the interest in a new integration between artificial and natural features to face environmental issues is increasing. This paper [1] intends to highlight the approach pursued by AURA research, an ongoing project that focuses on the use of biofilters (Nature Based Solution) in combination with sensors for environmental monitoring (Internet of Things), inserted in modular industrialized elements for a new generation of urban furniture. Therefore, the AURA project aims to contribute to the development of a real digital democracy, based on environmental data sharing and community engagement, representing a typical design driven innovation process that involves both the techno-science and social innovation levels.

Global warming, Data Sharing, Nature-Based Solutions, Connected Environment, Smart Cities

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The smart city concept, based on large, interconnected frameworks and on the use of *Information and Communication Technology* (ICT), has been developed as a strategy to deal with cities, which are becoming systematically more complex to fulfil the needs of citizens who inhabit them. Moreover, smart cities highlight important aspects of sustainability, which has turned in a highly desired ambition for the future of global urbanization, such as the need for responsible natural resource management, energy efficiency, and citizen engagement (Ratti, & Claudel, 2017).
Urban population growth, the improvement of life quality, the updating of obsolete infrastructure and the growing attention to environmental sustainability are some of the factors that are driving the increasing demand for smart city solutions, focusing on the encounter between the artificial and the natural world [fig. 01].
This paper intends to convey the approach provided in the AURA research, an ongoing project funded by the MISE Ministry of Economic Development, as part of a Partnership Agreement in which a research and development company concerning the botanical field and plant biofilters, a company active in the field of electronic sensors and ICT and a University Department as a Research Organization, are involved.
The project represents a typical *design driven innovation* in which the design plays the role of coordinating a complex design process between companies that have different technological knowledge, in this case regarding botanical researches or, on the other hand, sensor technology and IoT, in order to generate innovation processes that include both the techno-science and social innovation levels (Baek et al., 2018; Manzini, 2018; Manzini, Vezzoli, 2020; Mancuso,2018) [fig. 02].
The AURA project constitutes part of the new trends of the so-called *Green Economy*, strongly encouraged by the European Commission, which has among its primary objectives a Zero Environmental Impact Europe by 2050 (European Commission, 2020) and, specifically, of the *Green Infrastructure*s and *Internet of Things* (IoT), in which objects and people are interconnected through communication networks and that constantly release information both on their state and on the surrounding environment. The demand for inclusive and resilient cities, with green spaces and areas for leisure or work in which it is possible to develop a more sustainable lifestyle, is becoming more and more pressing from civil society. The need to rethink urban spaces by focusing the attention on the needs of citizens, rationalizing

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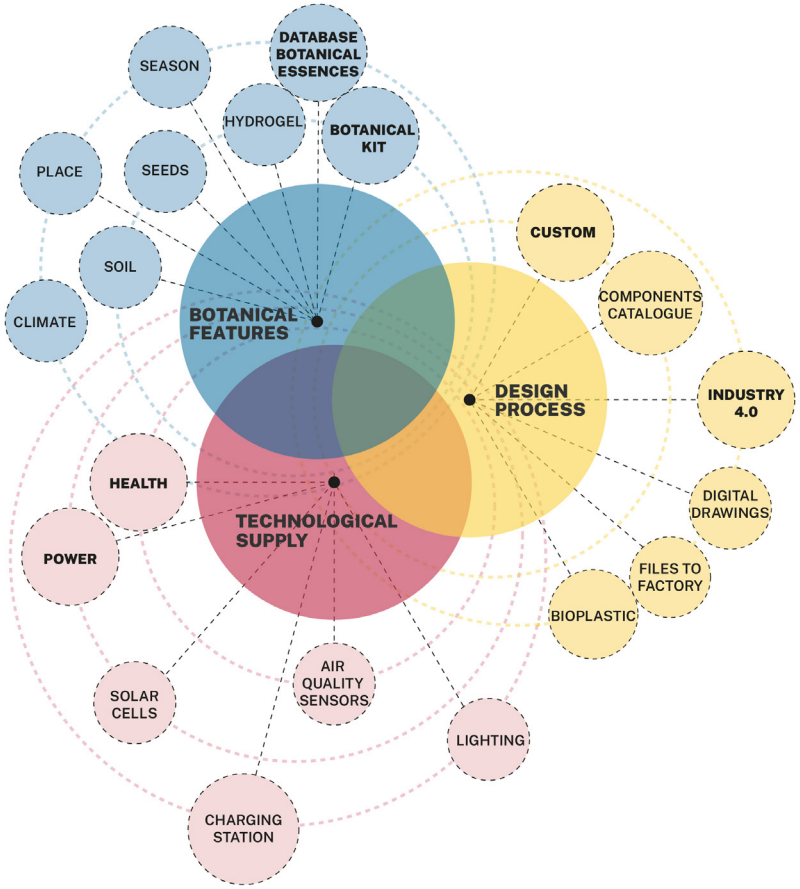
Wall plants

natural resources and making the provision of services more efficient, prefigures new scenarios that result in the transformation of cities into *smart cities*, or better said, into cities based on environmental intelligence, whose main mechanism is the ability to perceive what is happening around and to react accordingly in a dynamic way (Morone, Parlato, Nicolau, Sarno, 2020). In this direction, AURA research team is developing a new generation of *environment-friendly urban furniture* that, in addition to its original function, is provided of bio-absorbent vegetation referring to atmospheric pollutants, and smart, as it is equipped with intelligent sensors IoT, able to transmit climate data on urban pollution and vehicular traffic, plus other utility devices. These systemic, modular and multifunctional products, based on the connection between the *grey* component, the *green* component and the main structure, aim to explore a further innovative dimension compared to current smart urban furniture, able to help generate urban spaces with adaptive, interactive and informative skills. The purpose is to transform some of the most common types of urban furniture, such as seating, lighting, bus stops and info-points, into a system of hybrid artifacts capable of generating an urban monitoring network through a digital interconnection between sensor devices, annexed to the artifacts themselves and at the same time able to actively contribute in countering pollution, by capturing and reducing contaminants [fig. 03]. In fact, the concentration of botanical components in the devices is placed in order to generate microclimatic islands able to reduce the climate peaks in the urban context due to global warming. The data collected by the monitoring system will give eco-feedback (Hermsen, Frost, Renes, Kerkhof, 2016; Miller, Senadeera, 2017)

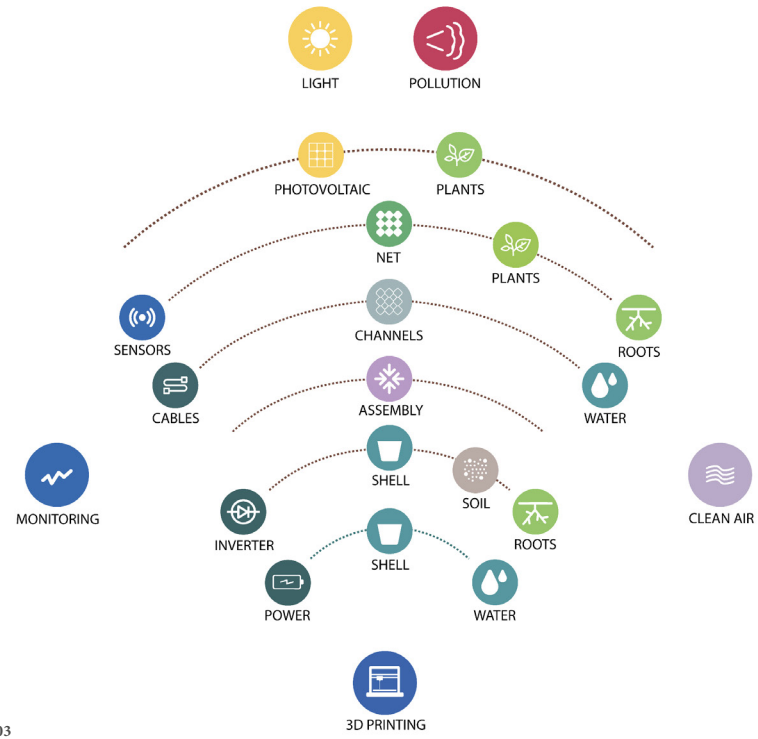
to companies, in order to implement initiatives to limit polluting emissions and maintenance; to local administrations, for the management of smart transportation and for the implementation of active and targeted responses to the monitored circumstances, and finally to citizens, through a software platform for the capture and formalisation of data. The connected environment, consisting of the network generated by the individual hybrid furnishings, firstly collects and transfers the data produced by the sensors to be compared and analysed and subsequently, by developing a system of digital communication interfaces with the new protocols of the IoT, processes and turns information accessible to citizens through a

02
Project approach methodologies combining botanical, design and technological aspects



02

mobile app or any interactive display placed inside the furnishings [fig. 04].
The intent is to enhance, through a democratic and pervasive availability of information by users, the establishment of a digital community that becomes active on environmental issues related to the air quality flowing in their urban context, by taking an active role in policy and administrative decisions. Through the provision of a network of sensors constantly connected to personal devices, not only the creation of a data absorption and release network is encouraged, but also a model in which public and private entities generate a system of connections that is essential for a progressive improvement of the solutions.
Therefore, the AURA project wants to represent a contribution to the development of a digital democracy, based on the environmental data sharing, that is also made possible by the proliferation of the data absorption network through a widespread distribution of the devices in the urban context, in this way citizen will be able to see



03
Hybrid devices functions diagram

04

real time pollution data which may lead them to make informed decisions about their consumption choices and practices. The project will provide also the possibility for the user to enter qualitative data of "satisfaction" of urban spaces in addition to the quantitative data detected by the sensors, in this way all data collected will be taken into consideration by the administrations to implement green policies through participatory design processes – bottom-up approaches (Sanguinetti, Dombrovski, Sikand, 2018).

04
Network generated through the hybrid devices in the urban context

Nature as a model

The natural elements in the anthropized context change the perception of the urban landscape and the life of the city itself, affecting the social balance. In addition, they encourage the exchange of practices, knowledge and mutual aid within the settled communities, triggering a system of connections both among the members of the community itself and between the human system and the natural one. The community of users becomes an active character. This activism arises from the interaction with the system and from the awareness of data, factors that lead to the birth of a digital democracy through sharing the elements that constitute the basis of environmental commitment. In fact, the measuring of the benefits produced by plants and the use of ICTs by communities will enable them to participate more fully in so-called knowledge societies (Eurocities, 2007) generating awareness of

05

05
Plants selection
in AURA research

their strategic function in urban developing for common good and providing administrations of specific tools to support green policies.
In order to introduce references and best practices a first reference is given by the results of NASA's Clean Air Studies, published in 1989 (Wolverton, 1989), subsequently detailed by various research and development groups on plant neurobiology around the world (Mancuso, 2017). NASA's approach was focused on the role of rhizospheric and phyllospheric microorganisms and their symbiotic relationship. More recent examples tried to integrate this first experiment by improving the use in indoor and outdoor spaces. Nowadays there is a growing interest in developing urban furniture solutions that integrate smart functions with botanical elements, both in the commercial sphere and academic research field.
Under the research point of view, it can be mentioned the design team Pnat, spin-off of the University of Florence and operating arm of the International Laboratory of Plant Neurobiology (LINV), which deals with studying solutions to integrate plants in the built environment and uses technology and design to make the action more effective. A well-known project developed by this team is "La Fabbrica dell'aria" designed for the city of Prato in 2019 [2].

Among the commercial solutions it can be pointed out the commercial product City Tree developed by the German start-up Green City solution [3]. City Tree is a system for the integration of a bench with a structure that acts as a biofilter. The biofilter combines specific moss crops with vascular plants that degrade particulate matter (PM) and dioxide of nitrogen. They are equipped with a self-sufficient structure containing a tank that collects rainwater automatically redistributed through an integrated irrigation system, and a system of sensors, all powered by solar panels and on-board batteries, which collect environmental and climatic data to regulate and control the unit and ensure survival of the plants, however, this project does not provide the possibility of using these elements in a systemic and widespread way to generate environmental monitoring in an urban setting, nor is clear the actual purifying capacity of the system.
The lack of information related to the physiology, genetics, and epigenetics of plants used outdoors and their capacity of uptake of different atmospheric pollutants implies the significant uncertainties in choosing urban vegetation for phytoremediation (Prigioniero, Zuzolo, Niinemets, Guarino, 2021)[4] [fig. 05][fig. 06].
None of these solutions deals with the definition of the actual phytoremediation capacity by the botanical component, understanding the interaction dynamics between plant organisms and the entire range of pollutants in each environment, which represents a very important step in obtaining a reliable assessment of the performance of NBS (Papazian, Blande, 2018). In this direction, the AURA botanical research team is developing an exposure chamber – an experimental system for measuring the capability of specific plants in capturing pollutants, metabolizing and ejecting them in the form of purified air simulating environmental conditions of a specific place in Real Time, Real Environment and Defined Space [fig. 07].
The Nature Based approach in the AURA project, therefore, is not limited to the use of plants as a natural element for air filtering and monitoring, but is also implemented as a model for the products and system running and structuring. The project, in fact, explores a new dimension of the integration of the artificial with the natural through the use of plants inserted in modular industrialized elements.
Natural systems can be considered as a model to reduce the environmental impact of anthropogenic systems. Plants breathe, see, hear and calculate with their whole body. They have a modular and cooperative architecture, comparable to a network, distributed and without com-

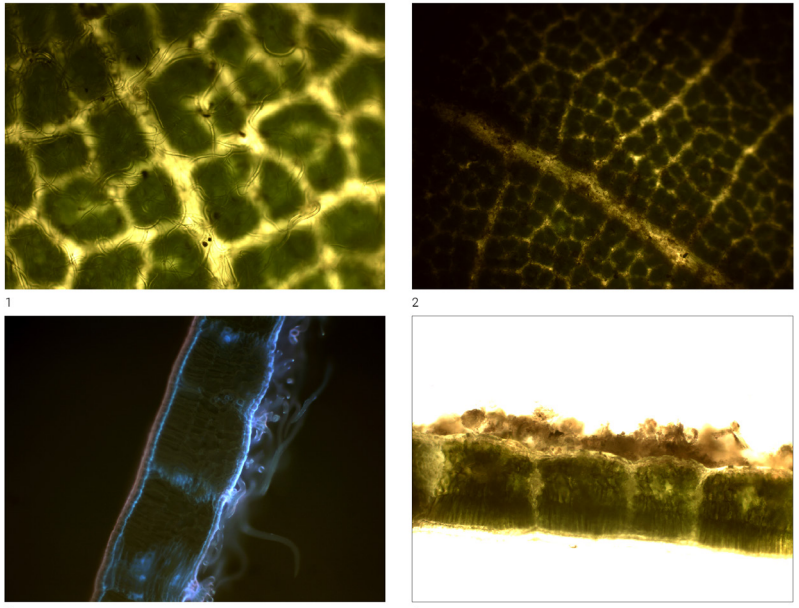
mand centres. Even though they do not have an organ similar to a central brain, plants are able to perceive the surrounding environment with a higher sensitivity and respond to stimuli by coordinating and collaborating to access the resources available in the soil (Mancuso, 2017). This operating model is used in AURA to make the individual pieces of furniture independent of each other, but still interconnected by the IoT intelligent sensors, and without the need for continuous and non-targeted maintenance.

AURA – Design choices

In order to translate the principles and the needs previously described into a tangible shape, the AURA system consists of a shell element that hosts both the plant and the sensor-based components, made of bioplastic and which, being produced by 3D printers, is scalable and modular [fig. 08].

The modular and interchangeable logic allows to get significant advantages in managing both technological updating, and the maintenance of the phytoremediation system and repair of the shell of the modular capsules, as each element, damaged or to be updated, can be easily replaced without creating slowdowns to the entire system. Moreover, through the implementation of hydrogels, scheduled irrigation not only contributes in reducing the complexity of the managing system, but it also expresses an environmental commitment in the rationalization of the water resource (6th point of the United Nations Organization Agenda 2030). In fact, in recent decades the ever-increasing demand and misuse of water resources have increased the risks of pollution and severe water stress in many parts of the world (United Nations Organization, 2015). Water is a finished raw material, equal to about 1400 million cubic meters that currently circulates constantly in the hydrological cycle at a planetary level. 97% is represented by salt water, while only 3% of the world's water is fresh, of which only about 1.5% is actually accessible (Gleick, 1996).

Therefore, it becomes clear that water management is one of the fundamental strategic objectives for the correct sustainable development of the planet, thus it needs to be integrated within the strategies of smart cities. Relevant design choices can be implemented by introducing new smart technologies for monitoring and saving water in our homes, regulations that impose restrictions on water consumption in the production phase, and the creation of new smart materials designed for the controlled release of water. The spread of these design directions would



06

06
1. Leaf surface with non-polluted cuticle
2. Leaf surface with PM polluted cuticle
3. Leaf section with visible leaf hairs
4. Leaf section with leaf hairs and adherent particulate matter

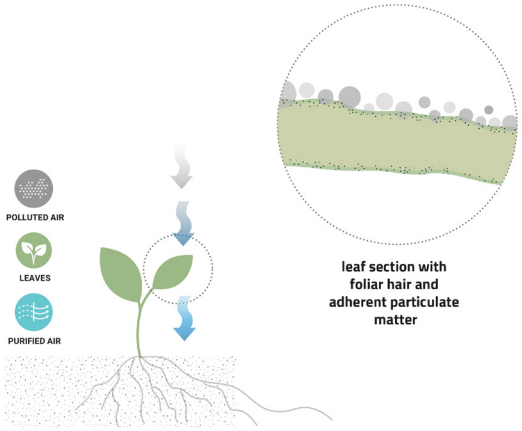
have a positive impact in all sectors belonging to the network constituted by IWRM (Integrated Water Resources Management). For this reason, within the AURA project, scheduled irrigation is a significant design feature, tested through the use of hydrogels, which permit to minimize human intervention, to program the irrigation process, with a gain in terms of water resources management and reduction of the plant engineering and maintenance complexities of the system.

As a result, all the botanical and techno-scientific processes find a formalisation within a chain of consistent and recognizable products, which represents the core of the design process.

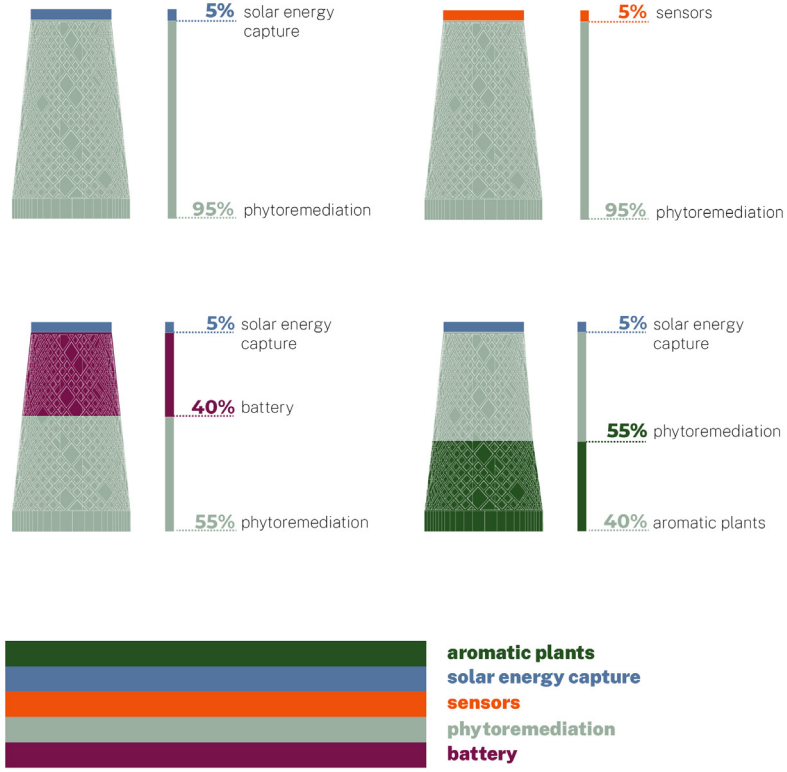
A design driven process

The urban furniture design of the AURA model makes the most of advanced tools for the configuration and design of customized solutions. In this phase, the system of connections, generated between the designer and the user and between the latter and the project, is fundamental. The user, in fact, takes an active role in defining the product, thus becoming a *prosumer* (Toffler, 1980), who is a designer consumer aware of his needs and active in the prefiguration phase of the project, which is made

customizable through the use of CAD/CAM modelling software, a tool that constitutes an indispensable point of connection between the development of the project and its digital production. Manufacturing 4.0, especially additive manufacturing, is a strong point in the adaptability of the elements to the different location and customization needs. The use of digital manufacturing also facilitates the encounter between the natural and the artificial world, or between the vegetal and electrical elements. Both components, in fact, are housed in modules which, being formalized through a generative parametric logic and produced through additive manufacturing, can be easily modified both according to the size of the stem and the root system as regards the plant part, and basing on the need to prepare anchoring cells for sensors or small containers for electrical parts or electronic processors. The modules, once the positioning of the two components is completed, are integrated into the main structure of the piece of furniture, in special inserts made using laser cutting machines. Each element of the urban furniture, after the prototyping and verification phases, is inserted, described and assembled virtually within a Digital Drawing Catalogue. This tool allows the user to easily define both the aesthetic shape, according to the urban environment in which it will be placed, and the functional characteristics, to be added or subtracted in relation to the specific needs, before placing the module into production. The modular approach and the digital realization contribute to facilitate the configuration of the products, but also to the sustainability of them as, in case



07
Plant diagram explaining the processing of pollutants in leaves



08

of breakage or malfunction, they permit to replace the single piece, easily replicable in case of elements made through manufacturing 4.0, without compromising the entire system, then managing to reduce maintenance operations. With the new non-linear methods of relation between production and use, a new business idea is generated, whose profits come mostly from the design and maintenance of the system, and whose components can be produced on site by the user through processes of self-production in conformity with the principles of the Industry 4.0. The files transfer from the company to the user, useful for the products realisation, generates a closer connection between them and above all allows the user to connect to a local production system (files to factory), limiting the usual consuming in energy and economic terms linked to standard logistics, thus taking part to the sustainable circuit of the circular economy.

08
Subdivision of the shell element's volume according to the functions that it has to host for the different applications in AURA urban furniture

The AURA project, therefore, intends to experiment new relationships between companies and customers, giving them the possibility of establishing a real community of self-producers, and conferring them an active role since the prefiguration and customization of the item, until the production phase. This is made possible by the use of digital manufacturing and files to factory transmission systems, helping users to actively contribute to the continuous evolution of the products themselves through the sharing of information and through a process of community learning.

NOTE

[1] Since the work was shared between the four authors, the editing of chapter 1 is attributable to Alfonso Morone, chapter 2 to Susanna Parlato, chapter 3 to Iole Sarno and chapter 4 to Guilherme Nicolau Adad.

[2] https://www.pnat.net/it/works/fabbrica-dellaria-manifattura-tabacchi/

[3] https://greencitysolutions.de/en/

[4] Photo source for figg. [04; 09]: Università degli Studi del Sannio di Benevento, Department of Science and Technologies. Research Laboratory: Integrated Animal and Plant Biology Systems for the Environment and Health.

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