sustainability

MDPI

Article

Sustainable Materials for Jewelry: Scenarios from a Design Perspective

Livia Tenuta *, Susanna Testa, Francesca Antinarelli Freitas and Alba Cappellieri

Department of Design, Politecnico di Milano, 20158 Milan, Italy; susanna.testa@polimi.it (S.T.); francesca.antinarelli@polimi.it (F.A.F.); alba.cappellieri@polimi.it (A.C.)
* Correspondence: livia.tenuta@polimi.it

Abstract: The complex nature of materiality describes the modern era and raises several questions, especially regarding sustainability. With the significant expansion of science and industry, the variety of materials available for designers is unlimited, and they are no longer forced to use materials that are provided directly by nature. Therefore, artificial materials are becoming more popular, offering new possibilities from a creative and innovative perspective. This introduces a new, challenging context for the jewelry design practice that should provide a positive and more sustainable approach. The paper aims to define future scenarios for sustainable materials for jewelry merging science and design. Cutting-edge movements are experimentally operating at the intersections of varied fields, occasionally deviating from conventional methods. Primarily, this article is intended to provide an overview of the current advancements in sustainable materials, emphasizing the strengths and potential benefits they could offer. Then, the paper investigates four scenarios as results of the intersection between science and design, highlighting the impact on the jewelry field. Four scenarios will analyze the materials currently employed in different fields and their possible application in future innovative tracks: designing sensibly; reshaping waste; modeling nature; making in lab. Lastly, this paper shows how crucial it is for designers and companies to take a proactive role and become agents to extend access to sustainable solutions.

Keywords: sustainable materials; design; materials; recycling

check for updates

Citation: Tenuta, L.; Testa, S.; Antinarelli Freitas, F.; Cappellieri, A. Sustainable Materials for Jewelry: Scenarios from a Design Perspective. *Sustainability* **2024**, *16*, 1309. https://doi.org/10.3390/su16031309

Academic Editor: Barbara Motyl

Received: 26 October 2023
Revised: 30 January 2024
Accepted: 31 January 2024
Published: 4 February 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Historically, the need for a transition toward a more sustainable society emerged from several environmental and social issues. In particular, the matter concerning the environment, namely the effects of production and consumption processes on the balance of natural habitats, began to be recognized in the latter part of the 1960s due to the rapid expansion and spread of industrialization [1]. In the field of jewelry design, this era also marked the beginning of a more conscious consideration of material sourcing and production processes, laying the groundwork for today's sustainability challenges in the industry. In this context, the role of design as a discipline is considered, and it is gaining more attention, especially regarding the materials used in the design and manufacturing process. "Design is the process by which abstract ideas assume concrete form and thus become active agents in human affairs. One of the critical parameters in any discussion of designed artifacts is material: what something is made of and how the material employed affects the form, function, and perception of the final design [2]".

The jewelry industry, which has evolved since the Sixties, now faces the task of balancing traditional craftsmanship with the urgent need for sustainable practices.

Today, design plays an essential role in providing sustainable solutions. Sustainable solutions aim for environmental, social, and economic well-being with the perspective of leaving future generations with a quality of life that is not inferior to the current one. The focus of designers, companies, and researchers is to transform unsustainable systems

of production and consumption by experimenting with and innovating the variety of materials offered. The discussion about sustainable materials grows more complex when considering resources with low environmental and social impact. The advent of new materials is generally treated as one of the determining factors in the development of modern design [2]. Also, the material selection process in the design field should be included in a broader context in which the life cycle of a product becomes a vital part. This approach is crucial in jewelry design, where the life cycle analysis can help in selecting materials that are more sustainable and ethically sourced.

In the Sixties, two primary notions were introduced. Firstly, the notion of life cycle thinking: everything from product conception to the design of product life cycle stages (i.e., all the activities needed to produce the materials and then the product, to distribute it, to use it, and finally to dispose of it) is considered a cohesive entity. Second, the idea of purpose-oriented consideration from an environmental perspective (i.e., design and evaluate a product's eco-friendliness, starting from its function rather than from the tangible product itself) [3].

From a sustainable design perspective, the concepts of life cycle thinking and functional thinking are real challenges for the future of jewelry design. Exploring the jewelry industry concerning sustainability is particularly interesting because it was and still is the result of integration processes between different methodologies and spheres. It contributes to providing a reinterpretation of the cultural changes that characterize contemporary. Using different languages can produce narratives that attribute meaning to the relationship between references, materials, technologies, products, and processes [4]. In today's context, contaminations are increasingly daring to meet contemporary challenges and generate innovation, and the sectors involved are growing in number and require specialized skills. Border territories [5], aimed at the most daring research and experimentation, arise from the intersection and integration of highly heterogeneous and specialized fields. It is precisely these exchanges that produce the sap for creativity and innovation. Today's designers, who are called upon to move in increasingly complex and multi-layered contexts and to mediate between polarities, diversities, and contrasts, share a propensity for a high degree of flexibility, which combines the contamination of knowledge as well as the need for practical experimentation and an evolved vision of applied innovation [6] for sustainable scenarios. The purpose of this paper is to explore sustainable scenarios by integrating science and design, focusing on the potential impacts these scenarios may have in the realm of jewelry design.

2. Materials and Methods

The following part of the paper will describe the methodology used to define the future scenarios for sustainable materials for jewelry, merging science and design. Through the identification of possible design directions, this paper intends to identify and evaluate opportunities for applying new sustainable materials in the jewelry field.

The strategy adopted in this study has been the research and inspiration of concepts, materials, and processes from sectors outside of jewelry. This methodological choice, which we call 'cross-fertilization' [7], explores how innovative solutions in various fields can be adapted and made relevant for the jewelry sector. The goal is twofold: on the one hand, identifying unprecedented opportunities for innovation in jewelry design and production; on the other hand, stimulating creative thinking that transcends the traditional boundaries of the sector. In analyzing the possible applications of these innovative solutions, it is essential to consider the heterogeneity of the jewelry sector. This sector includes not only high-end and fine jewelry but also broader categories such as fashion jewelry and avant-craft [8], which often depart from traditional processes to explore new frontiers in material experimentation. Recognizing this diversity, our study does not limit itself to the exclusive use of precious materials and stones but opens up to a broad spectrum of choices, materials, and techniques, many of which can derive from the practices and knowledge of different sectors. Integrating these ideas and approaches from other areas is a source

of innovation and an opportunity to promote more sustainable practices. Sustainability, an increasingly relevant theme across all production sectors, finds fertile ground in jewelry for exploring new materials, production techniques, and design philosophies, which can contribute to reducing environmental impact and encouraging more conscious and responsible consumption. Our study aims to demonstrate how cross-fertilization between sectors can be a powerful engine for innovation, opening up new possibilities for jewelry and contributing to a more sustainable and creative future.

The first step of the process is based on documentary research, data collection, case studies, and good practices from the last five years (2019–2023), exploring different fields, from architecture to textile, from medicine to automotive, and from art to leather goods. The documentary research is carried out in magazines dedicated to innovation in design (i.e., Designboom, Dezeen) through continuous consultation and the use of keywords; on Google Scholar by setting the search parameters "from 2019", "in any language" and "articles of any type", including patents; on Google News by selecting 2019 to today as the time frame. The following search keywords were used for all searches: sustainability, material, upcycle, recycling, design, architecture, medicine, design, fashion, green, innovation, carbon footprint, circular economy, waste, respect for the environment. This starting point gives an overview of the state of the art in sustainability, especially considering the existing sustainable materials used by different application sectors. Then, 40 case studies from start-ups, design studios, researcher's teams, and companies are identified and analyzed. The case studies are then selected for relevance and maturity status, with the aim of presenting in this article only the most significant projects that would avoid redundancy of information. Case studies are then organized per scenario, assigning specific keywords to each project identified and understanding the interconnection between them.

The scenarios are visualized through a coordinate plane, and they may be referred to as 'Design Orienting Scenarios' [6] as they present promising innovations involving a set of relevant case studies. This process, proposed by Jegou and Manzini [6], provides a framework for the design and realization of new products and product-service systems and helps approach a complex situation with a large number of variables in a systematic, precise, and organized way. The scenario-building methodology consists of a series of processes to systematically explore potential reconfigurations of the state of the art of products and services, which includes the following: collecting case studies; creating abscissae and ordinates in which the polarities have a connection with the research objective; dividing the case studies within the quadrants obtained from the intersection of abscissae and ordinates; and reconfiguring the meanings of the case studies into macro scenarios.

In the field of sustainability for jewelry, we find as relevant and discriminating elements the contribution of design for sustainable practices (design-driven/invention-driven) and the essence of the materials (testing nature/creating in a lab). The axis titles were assigned by the authors in an arbitrary manner, reflecting the distinct characteristics of the two opposite poles of material generation. The process of defining these titles began with selecting keywords that encapsulate the essence of the natural world on one side and, on the other, the realm of artificial creation within a laboratory setting.

The coordinate plane is created according to the polarities:

- Along the x-axis, the materials considered for their scientific qualities are shown: materials that come from the re-use of natural matter and materials created in the laboratory to avoid wasting natural resources.
- The y-axis organizes case studies considered from a design point of view. Case studies that converge toward design-driven approaches find their innovation in sustainability in design/user-oriented choices. Case studies that converge toward *invention-driven* are those in which sustainability comes primarily from material-related choices.

The polarities show the different possible variations in the fields of materials and sustainability.

Lastly, the coordinate plane is used to map the selected case studies from different sectors, leading to the definition of four scenarios. The organization of the coordinate

plane and case studies can be visualized in Figure 1. The x-axis presents *testing nature* and *creating in a lab* at the extremes that determine the origin of the materials, whether natural or lab-grown. On the y-axis, polarities are *design-driven* on the top and *invention-driven* on the bottom, where the discriminant is the drive for innovation. The four quadrants resulting from the intersection of x and y contain the case studies examined and positioned depending on their characteristics. The disposition of each case study's image within the quadrants is not meaningful and hierarchical.

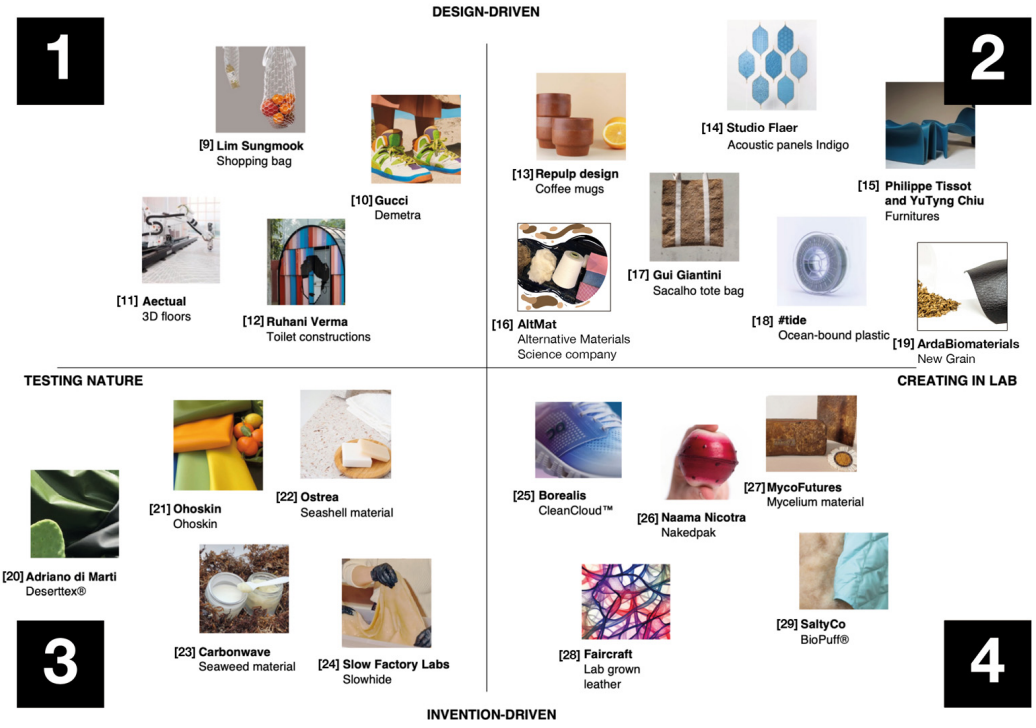

Figure 1. Coordinate plane and case studies. Lim Sungmook [9]; Gucci [10]; Aectual [11]; Ruhani Verma [12]; Repulp design [13]; Studio Flaer [14]; Philippe Tissot and Yu Tyng Chiu [15]; AltMat [16]; Gui Giantini [17]; #tide [18]; Arda Biomaterials [19]; Adriano di Marti [20]; Ohoskin [21]; Ostrea [22]; Carbonwave [23]; Slow Factory Labs [24]; Borealis [25]; Naama Nicotra [26]; MycoFutures [27]; Faircraft [28]; SaltyCo [29]. Source: Authors.

3. Results

This section of the paper presents the four different scenarios that emerged from the coordinate plane research, and each of them opens the possibility of creating a new class of materials. Starting from the common characteristics of the case studies within the four quadrants illustrated in Figure 1, a title and a description were identified to effectively shape the features of the scenario. It is important to highlight that these scenarios are not to be considered market trends but rather as trajectories at varying stages of development, which can guide design practice in the jewelry field.

The four scenarios, as represented in Figure 2, are as follows:

1. Designing sensibly: materials that take into account the lifespan of the product and the possibility of being recycled after use;
2. Reshaping waste: materials created from the disposal of waste coming from different sectors;
3. Modeling nature: materials originated from natural resources that can be upcycled and produce new materials;
4. Making in lab: materials created in a laboratory starting from cells or polymers that experiment with new technologies and processes.

Figure 2. Sustainability for jewelry scenarios. Source: Authors.

In sustainable jewelry, many products, technologies, or techniques come from areas seemingly distant from fashion. They only arise from the convergence of different disciplines and domains. Architecture, medicine, art, and automotive are a few of the areas where the majority of the advancements we observe are taking place.

In the following paragraphs, some examples are shown to highlight the general trajectories and corresponding scenarios in design, science, and innovation. Many disciplines are interconnected, and transversal research is carried out to generate new knowledge in the materials design field.

3.1. Designing Sensibly Scenario

The first scenario refers to the role of design in processes and the choice of a specific material from a circular perspective. It highlights that the decisions made at the design stage of a product influence its lifespan, including the possibility of being repaired or recycled. 80% of a product's environmental impact is influenced by decisions made at the design stage [30].

In the context of a circular economy, designers need to consider regenerating nature, reducing waste and pollution, and circulating products and materials. It is not just about choosing eco-friendly materials in the making of products. However, it is also about building a project using minimal materials and avoiding additional and unnecessary materials [31].

Also, from a circular design perspective, it is essential that the actors, such as designers and companies, encourage users to reuse products and their materials [32]. Materials can be reused by upcycling, recycling, and downcycling. Basically, upcycling means raising the quality of the material, recycling means keeping it at the same level and downcycling means lowering the quality [33].

One of the case studies considered is the multi-use shopping bag called "Sustainable Shopping Bag (SSB)" designed by Lim Sungmook in 2020 [9]. The Korean designer aimed to create a lightweight shopping bag to replace disposal shopping bags. This would encourage customers to recycle and reuse them as often as possible. The mesh-structured design can be used several times, and it was created using eco-friendly materials, 100% of which can be recycled. The net structure developed by Sungmook uses minimal fabric, and it was

designed to be manufactured without any additional adhesives or additives. In order to do that, the origami technique was studied and experimented with. After adopting the net structure, the designer tested the function and usability of the product and organized the net pattern algorithm to disperse the weight and create space effectively. Despite its lightweight appearance, the mesh is strong enough to hold up to 7 kg. The material used for this design can be considered sustainable and offers an alternative to disposable plastic shopping bags.

Moving to sustainable construction, the leading target group for this case study is the Indian population. The project is called "Toilet 01" [12], and the central concept of the project regards sustainable modularity. In 2022, Amritsar native Ruhani Verma had the idea to build India's first carbon-negative public toilet using environment-friendly bricks made of 100% recycled or recyclable material and three times stronger than a traditional red clay brick. Approximately 30% of the brick utilized in the toilet consists of single-use plastic, and the remaining 70% comprises waste and silica dust. Every material used in the structure is recyclable, and no cement mortar was used. Each toilet unit is built using two SPB-made items, specifically 1000 flat planks and 150 Lego blocks. These blocks are fully customizable and repurposable, thereby enhancing the efficiency of this eco-friendly toilet as a conscious solution. The interesting aspect of this project concerns the modularity and adaptability of individual elements. Designing kits and not finished products helps to extend the products' lives and transform them as needed.

The last case study for the designing sensibly scenario refers to the fashion industry. In 2021, Gucci launched a sustainable material called Demetra [10]. It is produced entirely in Italy and integrates innovation and circular design pillars: production efficiency and using sustainable, animal-free, and renewable raw materials. After two years of research and development, Demetra was able to combine durability and scalability. It contains at least 70% plant-based and renewable raw materials such as viscose, wood pulp, and bio-based polyurethane. The most important aspect of this project is that Demetra's waste will be reused to raise the quality, in line with Gucci's circular economy initiative, Gucci-Up, focused on upcycling, through which Gucci recovers leather and fabric waste generated in the production processes. In this project, sustainability is a concept that encompasses circularity and inclusivity in a synergetic way. Strengths and potential benefits of this scenario are shown in Figure 3.

1. DESIGNING SENSIBLY			
	"Sustainable Shopping Bag" by Lim Sungmook	ECO-FRIENDLY MATERIALS	*Utilizes 100% eco-friendly materials; encourages sustainability by promoting the use of recyclable materials.*
		REUSABLE DESIGN	*Designed for multiple uses; aligns with environmental goals by minimizing single-use plastic waste.*
		MESH-STRUCTURED DESIGN	*Showcases innovative design thinking by incorporating origami techniques.*
		ADHESIVE-FREE MANUFACTURING	*Manufactured without the use of additional adhesives or additives; reduces environmental impact.*
		FUNCTION AND USABILITY	*The net pattern algorithm disperses weight effectively, ensuring practicality in everyday use.*
		STRENGTH AND DURABILITY	*Despite its lightweight appearance, the mesh structure is strong enough to support up to 7kg.*
		SUSTAINABLE ALTERNATIVE	*Presents a sustainable option, offering an environmentally friendly alternative to disposable plastic bags.*
		BEHAVIORAL CHANGE	*Encourage customers to adopt sustainable practices by choosing a reusable and recyclable shopping bag.*
	"Toilet 01" by Ruhani Verma	CARBON-NEGATIVE INNOVATION	*Commitment to environmental sustainability by actively reducing carbon emissions.*
		SUSTAINABLE MODULARITY	*Allows for adaptability, customization, and repurposing of individual elements, reducing waste.*
		RECYCLED AND RECYCLABLE	*Reinforces the project's commitment to a closed-loop system, supporting circular economy principles.*
		INNOVATIVE SPB	*Incorporates 30% single-use plastic and 70% waste and silica dust, reducing environmental impact.*
		STRENGTH AND DURABILITY	*SPB bricks are three times stronger than traditional red clay bricks; ensures structural integrity and longevity.*
		NO CEMENT MORTAR	*Reduces the environmental footprint by avoiding the energy-intensive production of cement.*
		CUSTOMIZATION	*Enhances the efficiency of the toilet while allowing for creative adaptations and alterations as needed.*
		MODULARITY AND ADAPTABILITY	*Designing kits rather than finished products emphasizes the modularity and adaptability of individual elements.*
		EXTENDED PRODUCT LIFE	*The focus on designing kits contributes to extending the life of the products; supports a circular economy model.*
	"Demetra" by Gucci	UPCYCLING AND CIRCULAR DESIGN	*Embraces upcycling as a key element of the material's production process; adopts circular design principles.*
		PRODUCTION EFFICIENCY	*Integrates production efficiency as a pillar, emphasizing resource optimization in the manufacturing process.*
		RESPONSIBILITY	*Utilizes sustainable, animal-free, and renewable raw materials; aligns with ethical and environmental considerations.*
		HIGH QUALITY PERFORMANCES	*Demonstrates that sustainable materials can meet the performance standards of traditional materials.*
		ECO-FRIENDLY	*Reduces reliance on non-renewable resources and fosters the use of eco-friendly alternatives.*
		WASTE RECYCLING AND REUSE	*Supports a closed-loop system; minimizes environmental impact of waste generated in the production processes.*
		CIRCULAR ECONOMY INITIATIVE	*Comprehensive commitment to circularity, integrating sustainability into the core of the brand's practices.*

Figure 3. "Designing Sensibly" strengths and potential benefits. Source: Authors.

3.2. Reshaping Waste Scenario

In the second scenario, the sustainable transition demonstrates the need for a radical change in rethinking the design process and the materials used. There are unlimited opportunities to create new materials, especially by producing materials with a positive impact. Within this context, designers are considering materials made from waste otherwise destined for disposal.

Recently, many designers have found interest in the enormous waste and the possibility of creating something with a 100% biodegradable composition. Several projects focus on how waste can be upcycled. Many sectors of applications are taken into consideration, such as the food industry (garlic and orange peels), the industrial sector (wind turbines, silicon, and polyurethane molds), the agriculture sector (discarded landfills generated by shellfish farming and crop waste), and the ocean area (ocean-bound plastic waste materials). Starting in the fashion industry, waste can be transformed into fibers and yarns.

Since 2020, AltMat [16], an Alternative Materials Science company, has transformed biomass from agriculture, food, medical, and industrial crops into natural fibers and yarns. Therefore, they are creating innovative materials and experimenting with regenerative technologies using natural cellulose fiber from upcycling disposal waste. They offer an inclusive material with a circular life cycle that, unlike cotton, does not require excessive water for its production.

Another company working in the fashion and automotive industries is Arda Biomaterials [19]. This company transforms waste feedstocks into smarter circular biomaterials, starting from grain and creating a new material called New Grain™. The company uses the amount of brewers' spent grain (BSG), which is widely available and typically sold at a low price, as animal feed. Instead of using it in the traditional way, Arda Biomaterials is converting wheat into a sustainable, leather-alternative product. Manufacturing New Grain™ requires using plastic-free ingredients, including materials such as plant proteins, plant fibers, and non-toxic chemicals. Also, this experimentation can potentially empower local supply chains, incentivizing them to produce New Grain™ wherever a brewery exists, creating a positive impact on a global scale.

Waste disposal offers many opportunities for sustainable design and innovative materials, and designers often decide to take advantage of food waste disposal.

The Sacalho tote bag by designer Gui Giantini [17], a member of the Product and Services Development Laboratory (LDPS) of the Faculty of Engineering at the University of Porto, uses an entirely biodegradable composition, resourcing the waste of garlic peels for its production. The aim of the project is to promote an alternative to the materials currently on the market, which, although bio-based, still have a significant environmental impact due to their cultivation and production processes. Considering, on one hand, the adverse environmental effects caused by the textile sector and its production and, on the other hand, the enormous amount of food waste produced each year in Portugal, this project focused on creating a bio-textile from food waste. At first, the designer explored the composition of various food residues. Afterwards, he conducted an attentive analysis and evaluation to find physical properties similar to those of cotton and TNT fabrics, and garlic peels were the most suitable.

Also, Victoria Lièvre and Luc Fischer, founders of Repulp Design [13], decided to work with food waste. Interested in the enormous amount of waste created by orange peels discarded daily in bars, they decided to turn this food waste material into products. The process involved drying the peels, pulp, and seeds before being ground into powder and heated. The final product resulted in biodegradable coffee cups that can be recycled or composted at the end of their lifecycle. Strengths and potential benefits of this scenario are shown in Figure 4.

2. RESHAPING WASTE			
	"AltMat"	DIVERSE BIOMASS UTILIZATION	*Transforms biomass from agriculture, food, medicinal, and industrial crops, showcasing a versatile approach.*
		NATURAL FIBERS PRODUCTION	*Specializes in creating natural fibers and yarns from transformed biomass, as alternatives in the textile industry.*
		INNOVATIVE MATERIAL	*Explores the potential of natural cellulose fiber from upcycled disposal waste, providing eco-friendly alternatives.*
		REGENERATIVE TECHNOLOGIES	*Demonstrates a commitment to adopting environmentally friendly practices in material production.*
		CIRCULAR LIFE CYCLE	*Offers materials with a circular life cycle, reducing waste and promoting the reuse of resources.*
		UPCYCLING DISPOSAL WASTE	*Minimizes the environmental impact associated with traditional waste disposal methods.*
		WATER-EFFICIENT PRODUCTION	*AltMat's biomaterials do not require excessive water for production, addressing concerns related to water scarcity.*
	"New Grain" by Arda Biomaterials	TRANSFORMATION OF WASTE	*Transforming waste feedstocks into circular biomaterials in both the fashion and automotive industries.*
		DIVERSIFICATION OF WASTE	*By converting wheat into a leather-alternative product, showcases the potential for diversifying waste feedstocks.*
		PLASTIC-FREE INGREDIENTS	*Use of plastic-free ingredients, including plant proteins, plant fibers, and non-toxic chemicals.*
		EMPOWER LOCAL SUPPLY CHAINS	*Empower local supply chains, creating opportunities for production wherever a brewery exists.*
		SUSTAINABLE DESIGN PROMOTION	*Waste disposal as an opportunity for sustainable design, repurposing waste feedstocks into eco-friendly materials.*
		POTENTIAL FOR COLLABORATION	*Collaboration with breweries for the sourcing of brewers' spent grain can create mutually beneficial partnerships.*
		CIRCULAR ECONOMY PRINCIPLES	*Circular biomaterials, waste transformation, and promotes resource efficiency and waste reduction.*
	"Sacalho" tote bag by Gui Giantini	ENTIRELY BIODEGRADABLE	*Aligning with sustainability goals and reducing environmental impact compared to non-biodegradable alternatives.*
		ALTERNATIVE MATERIALS	*The project offers a sustainable alternative to conventional materials.*
		BIO-TEXTILE FROM FOOD WASTE	*Recognizes the dual challenges of environmental effects from the textile sector and the abundance of food waste.*
		EXPLORATION OF VARIOUS FOOD	*Explores a diverse range of food residues such as coffee grounds, wood ash, garlic, carrots, onions, potatoes...*
		CIRCULAR ECONOMY	*Repurposes food waste, reduces reliance on virgin materials, encourages a closed-loop approach to resource use.*
		COLLABORATION	*As a part of the Product and Services Development at the University of Porto, the project highlights the potential for local collaboration between academic institutions and designers, fostering innovation in sustainable practices.*
	"Repulp Design" by V. Lièvre, L. Fischer	INNOVATIVE USE OF FOOD WASTE	*Specifically addressing the significant amount of waste generated by orange peels in bars.*
		END-OF-LIFE OPTIONS	*The biodegradable coffee cups from Repulp Design can be recycled or composted at the end of their lifecycle.*
		REDUCTION OF WASTE	*Not only repurposes waste but also reduces the overall environmental impact of the hospitality sector.*
		CONSUMER-FRIENDLY OPTIONS	*Caters to consumer preferences for sustainable products and encourages responsible waste disposal behavior.*
		AWARENESS OF DAILY HABITS	*Commonly discarded materials like orange peels can be transformed into valuable, functional items.*
		LOCALIZED SOLUTIONS	*Encourages businesses and communities to address specific waste challenges.*

Figure 4. "Reshaping Waste" strengths and potential benefits. Source: Authors.

3.3. Modeling Nature Scenario

The modeling nature scenario is represented by materials that can be found and sourced directly in nature. Natural materials such as wood, stone, wool, and cotton can be used in interior design, architecture, construction, fashion, and food. They can boast considerable advantages; for instance, they can be considered excellent insulators that are able to make thermal barriers. Usually, natural materials are more expensive than synthetic materials, but they compensate for durability. Many natural materials are historically more sustainable than others [34]. Wood is considered a popular option for green and sustainable choices because it is readily available and easily converted into many products. Wood can also be made from recycled products, which can reduce deforestation and environmental degradation. Therefore, it is preferable to use recycled natural materials to reduce the environmental impacts of the manufacturing of natural materials [35].

Some projects that aim to create more sustainable materials, starting with natural resources, are experimenting with natural materials such as seashells or seaweeds.

The company Ostrea [22], a Breton start-up, transforms shell waste, creating eco-friendly, aesthetic, durable, and low-carbon interior and exterior design materials. Its goal is to enhance this natural bio-mineral to create worktops, washbasin tops, furniture panels, and coatings. The innovative Ostrea material is produced in France. It is composed of 35% mineral matrix and 65% shell flakes and is 100% recyclable. These flakes can be made from mussels, oysters, or scallop shells.

Also interested in innovating natural materials, Carbonwave [23] provides a sustainable and regenerative platform for carbon-neutral and innovative manufacturing. Starting from seaweed, they have created a range of products for agriculture, textiles, personal care, and cosmetics through a cascading biorefinery model they developed. Their products help reduce emissions from fossil fuels and traditional plastics while minimizing waste, and they overcome challenges from environmental stresses like heatwaves, droughts, and soil exhaustion. Also, the company is creating a plant-based fabric that relies on extracting structural polymers to form films stronger than the seaweed itself and competitive with the strength of other vegan textiles without relying on polyurethane plastic for structure and strength. Lastly, they experimented with innovative solutions across the cosmetics and skin-care sectors. They have created SeaBalance Emulsifiers that solve the issue related to

the presence of harmful fossil fuel derivatives by utilizing an all-natural process. Strengths and potential benefits of this scenario are shown in Figure 5.

3. MODELING NATURE			
	"Ostrea"	ENVIRONMENTALLY FRIENDLY	*Ostrea's process transforms shell waste into eco-friendly interior and exterior design materials.*
		DURABLE CONSTRUCTION	*Long-lasting solutions for interior and exterior design applications, reducing the need for frequent replacements.*
		LOCAL PRODUCTION	*Promotes local manufacturing and reducing the environmental impact associated with long-distance transportation.*
		VALORIZATION OF BIO-MINERAL	*Valorize shell waste, adding value to what would otherwise be considered waste.*
		COMPOSITION FOR SUSTAINABILITY	*35% mineral matrix and 65% shell flakes, demonstrates a balance that enhances both durability and sustainability.*
		RECYCLABILITY	*The material is 100% recyclable, by allowing for the reuse of resources in future applications.*
	"Carbonwave"	SEAWEED-BASED PLATFORM	*A new seaweed platform for carbon-neutral, innovative manufacturing.*
		DIVERSE RANGE OF PRODUCTS	*Development of a diverse range of products for agriculture, textiles, personal care, and cosmetics, demonstrating the versatility of seaweed-based materials.*
		CASCADING BIOREFINERY MODEL	*Carbonwave employs a cascading biorefinery model, maximizing the utilization of seaweed by extracting multiple products across different industries, promoting efficiency and sustainability.*
		EMISSION REDUCTION AND WASTE MINIMIZATION	*Reducing emissions from fossil fuels and traditional plastics, while also minimizing waste through the utilization of seaweed-derived materials.*
		RESILIENCE TO ENVIRONMENTAL STRESSES	*The products developed by Carbonwave overcome challenges posed by environmental stresses such as heatwaves, droughts, and soil exhaustion, providing solutions for sustainable agriculture.*
		PLANT-BASED FABRIC INNOVATION	*A sustainable alternative to traditional textiles, avoiding the need for polyurethane plastic for structure and strength.*
		REDUCED RELIANCE ON POLYURETHANE PLASTIC	*By creating a fabric without relying on polyurethane plastic, Carbonwave addresses concerns related to the environmental impact of traditional plastic-based materials.*
		HOLISTIC APPROACH TO SUSTAINABILITY	*Carbonwave's initiatives demonstrate a holistic approach to sustainability, spanning multiple industries and addressing various environmental challenges, contributing to a more eco-conscious future.*

Figure 5. "Modeling Nature" strengths and potential benefits. Source: Authors.

3.4. Making in Lab Scenario

During the first part of the last century, synthetic materials have made considerable scientific and technical progress to enable mass production of qualitatively superior products [36]. Today, designers are approaching synthetic biology to create new sustainable materials. Starting from living cells and organisms and integrating material science concepts, their goal is to redesign living systems as responsible materials with new functionalities. In this emerging scenario, natural fibers are giving way to man-made, artificial materials like polyester, acrylic, and nylon. These materials are more cost-effective and simpler to produce on a large scale, and they easily create consistent hues, lengths, and strengths of materials that can be tailored according to particular needs [37].

The broad and exciting range of possible applications has substantial implications for addressing grand challenges in health, biotechnology, and sustainability [38]. For instance, genetic circuits can be implemented to produce chemicals and biopolymers (such as DNA or proteins), produced either constitutively or in response to environmental cues, which can then be used to engineer materials [38]. Some projects specifically focus on environmental issues, and designers are experimenting with turning natural resources into innovative and more sustainable materials created in a laboratory.

The first case study tackles the issue of climate change, prompting designer Naama Nicotra to use natural edible materials combined with agar, a primary ingredient derived from algae, to create a range of decomposable food packaging. The food wrap series named "NakedPak" [26] delves into the idea of food dishes without any packaging. It goes back to natural and sustainable traditional solutions that have been replaced by plastic and paper packaging. Naama Nicotra started researching different materials that could function as packaging materials and be eaten with their contents to find a natural, soluble bioplastic. Consequently, the NakedPak composition utilizes algae as the main ingredient to create bioplastic packaging. The final material is transparent, flavorless, and can be manufactured as a flat sheet or a 3D shape. Seasonings and sauces can be embedded in the NakedPak organic material, thus producing flavored wrappings that dissolve in hot water. Within NakedPak, the designer also addresses the issue of hygiene through the "Apple Principle". This principle entails that food should be washed before consumption, similar to an apple sold in bulk, exposed to dirt, and transported in a sack. NakedPack demonstrates how material exploration and experimental investigation can potentially lead to a behavioral

and mental shift, paving the way for a novel, sustainable, and innovative path. In this instance, the project successfully addresses the problem of food packaging waste.

Some alternative materials produce low carbon emissions throughout the production process and supply chain. This is the case of mycelium-based leather by MycoFutures [27]. This innovative materials cleantech startup interconnects mycology, mushroom cultivation, and the study of biomaterials to create sustainable material options for the fashion industry. Many companies from different sectors cultivate mycelium, the complex root system of fungi because it grows and decomposes quickly, releasing carbon back into the soil. MycoFutures aims to create products with the look and texture of skin while reducing environmental impact. The three critical areas of the company's technology are strain selection (even in one fungal species, there are many strains with different characteristics); growth parameters such as the substrate composition, environmental control, growth container, and vertical farming systems (they allow for efficiency and automation, reducing energy consumption and carbon footprint); and processing methods including halting the growth, stabilizing the raw material, dyeing, and coating.

The food field also suggests many ideas for materials created in the laboratory. Recently, there has been much talk surrounding cultivated meat, especially after Upside Foods and Good Meat received final U.S. Department of Agriculture (USDA) approval to sell lab-grown meat for the first time in the U.S. Lab-grown meat, or meatless meat, is a material produced in laboratories that can offer the same protein source without harming the planet. The production of in vitro meat does not require animal killing or farming. Additionally, it carries a reduced environmental footprint, diminishes health issues, and is more cost-effective.

Furthermore, while perhaps not as widely discussed, cultivated—or lab-grown—dairy could also be set to take off and could offer environmental benefits comparable to cultured meat. Recently, lab-cultivated dairy is also beginning to be thrown into the mix of animal-free options, which, if it gains traction, could potentially serve as an eco-friendly alternative to conventional dairy. Strengths and potential benefits of this scenario are shown in Figure 6.

4. MAKING IN LAB			
	"NackedPack" by Naama Nicotra	NATURAL EDIBLE MATERIALS	*Utilizes natural edible materials, including agar derived from algae, to create decomposable food packaging.*
		ALTERNATIVES	*Promotes sustainable and environmentally friendly alternatives to traditional plastic and paper packaging.*
		BIODEGRADABLE	*Designed to decompose, reducing the environmental impact of food packaging waste.*
		VERSATILE MANUFACTURING	*The bioplastic packaging can be manufactured as a flat sheet or a 3D shape, providing versatility in packaging.*
		BEHAVIORAL AND MENTAL SHIFT	*Demonstrates how material exploration and experimental investigation can lead to a behavioral and mental shift.*
		WASTE REDUCTION	*Contributies to waste reduction.*
		POTENTIAL FOR INDUSTRY	*Sets an example for the industry by showcasing a successful integration of natural, edible materials into packaging.*
	"MycoFutures"	LOW CARBON EMISSIONS	*Mycelium-based leather, produces low carbon emissions throughout the entire supply chain.*
		SCIENCES INTEGRATION	*Integrates mycology, mushroom cultivation and biomaterials research trough a holistic approach to sustainability.*
		COMPREHENSIVE PROCESSING METHODS	*Encompasses various processing methods, including halting the growth, stabilizing the raw material, dyeing, and coating, ensuring a well-rounded and sustainable approach to material development.*
		EFFICIENCY AND AUTOMATION	*Incorporates vertical farming systems for mycelium cultivation, showcasing efficiency and automation.*
		POTENTIAL FOR FASHION INDUSTRY	*Emphasizes the potential for broader adoption of eco-friendly materials in the clothing and accessories industry.*
		CIRCULAR ECONOMY	*USES a natural material that grows and decomposes quickly, contributing positively to the overall ecosystem.*
	Lab-Grown Meat and Lab-Cultivated Dairy	REDUCED ENVIRONMENTAL IMPACT	*Reduces the environmental impact associated with traditional animal farming, contributing to sustainability efforts.*
		ELIMINATION ANIMAL KILLING	*Eliminates the need for animal killing/farming, addressing ethical concerns associated with livestock agriculture.*
		ALTERNATIVE SOURCE	*A viable alternative protein source, providing consumers with an alternative option.*
		DIMINISHED HEALTH ISSUES	*Diminished health issues compared to traditional animal farming (antibiotics, hormones, and diseases).*
		COST-EFFECTIVENESS	*More cost-effective, potentially making sustainable alternatives more accessible to a broader market.*
		DIVERSIFICATION	*Diversification of animal-free options, catering to a growing demand for sustainable and ethical choices.*

Figure 6. "Making in Lab" strengths and potential benefits. Source: Authors.

4. Discussion

The four scenarios described above capture the current state of the art among sustainable materials and outline trajectories for the future. How can they be applied to jewelry if they seem highly distant?

In the dynamic field of jewelry design, innovative solutions often emerge from unexpected sources. Take the zipper as an example. The zipper, invented in 1851, is a widely used device to fasten fabric edges. Elias Howe patented the first automatic clothing closure in 1851. Whitcomb L. Judson later developed the slide fastener in 1893. Gideon Sunback

redesigned it in 1913, and the term 'zipper' was coined in 1933 by B.F. Goodrich, who used it on a rubber boot [39]. Then, the zipper quickly spread to the clothing of American sailors and soldiers and only later to children's clothing for its ease of use. It is clear that the zipper, although it was a smart intuition, proved to be slow in industrialization and application, and certainly at the beginning, a product was used for its practicality rather than its aesthetics. Nevertheless, it was adopted in the jewelry field in 1954. The Zip by Van Cleef and Arpels is a masterful creation that transcends traditional boundaries. Like an actual zipper, the necklace is equipped with a slider in the shape of a woven gold tassel that allows it to be closed and thus transformed into a bracelet. Stealing the wardrobe of sailors and aviators, the Zip is a best practice of innovation through cross-fertilization [40].

Similarly, the four scenarios described above can find possible and innovative applications in the jewelry sector.

The first scenario, "design sensibly", promotes the importance of designing for sustainable practices. It is essential, during the design phase, to find solutions that use as few resources or as little waste as possible. This is not new in the jewelry world. An example of this is filigree, which came back into fashion in the early 1800s due to a shortage of resources and allowed various pieces of jewelry to be made with a limited amount of gold. It is a design and technical choice that responds to the need for a conscious use of materials.

To examine more current case studies, the Orchid by Studio Minale Maeda designed for Chi Ha Paura (. . .?) [41] is a 3D-printed orchid lapel pin that can be applied to a buttonhole or clipped to any clothing item through its stem. The form of the flower is created each time it is purchased and is influenced by several factors, such as location, earth quality, climate, and time of year. If buyers are not satisfied with the result, they can wait for varied circumstances to 'grow' a different orchid. Subsequently, the users receive only the 3D file, which can be printed whenever they wish and in the place most convenient for them. Emerging technologies allow designers to actively involve end users online throughout the design and manufacturing phases to produce items that best meet the consumers' requirements in terms of wearability and aesthetics. At the same time, they are produced on demand, thereby avoiding overproduction and waste [42]. This is just one of the possible applications and advantages that orbit around the broader field of additive manufacturing. As identified in the "design sensibly" scenario, all actions aimed at reducing waste or shortening the supply chain—including on-demand manufacturing and modular product development—represent a real direction that companies are moving toward and that consumers recognize as added value. Furthermore, modular products play a role in global sustainability because they offer the opportunity to mix and match components in numerous ways and can thus better meet different customer needs. Modular jewelry grants the wearer the ability to manipulate set components, combine and merge them, and wear them in diverse styles. This is exemplified in Massimiliano Adami's Precious Molecules [43], a collection of divisible elements in assembled parts, each constituting the essence of the foundational aspects of the ornament as a whole. The units are designed to be assembled as components of a set, as in the Drilling Lab Project [44], which creates a precious alphabet re-envisioning the designs of industrial clamps.

The second scenario, "reshaping waste", encourages creativity using circular approaches—remember that producing enough gold for a simple wedding ring wastes almost 20 tons of rock. Therefore, since 2006, Monique Péan [45] has exclusively used reclaimed gold and platinum. Additionally, the designer's recycling efforts extend beyond metals to include the reuse of precious stones. She travels globally to source materials that bypass industrial extraction. She ensures ethical practices by collaborating with local craftsmen and consulting researchers to evaluate the sustainability of her discoveries. Silver, gold, and other metals are recycled from existing supplies, such as discarded electronics like televisions, mobile phones, and computers, and offer a green alternative to the socially and ecologically damaging methods of traditional mining. In this technological era, with rapid progress and planned obsolescence, vast quantities of electronic waste accumulate.

Moreover, since gold is a precious material worth repurposing, it facilitates the co-recovery of numerous less-prized metals and ceramics. While some might argue reusing gold is not a new concept given that the jewelry trade has been reusing metals since craftsmen began forging gold and silver accessories roughly 5000 years ago and the method of melting down gold and silver is a routine in the sector, this practice remains highly noteworthy. The Campana Brothers [46] in their design practice give value to local materials that are often discarded to safeguard the environmental heritage. For the Campanas, materials, whether they are simple and understated or opulent, always pave the way for their creative journey, which ranges from chairs to lights, from fashion accessories to jewelry. Bones' Structure, for example, is a modular necklace made up of a set of leftover leather parts, which the consumer can rearrange in multiple styles using magnets. Manufacturing waste typically bears irregularities that make each item unique and subtly flawed.

The third scenario, "modeling nature", proposes a reconnection with nature, which has always inspired jewelry. Here, design could find its highest expression using materials of natural origin. Maria Carelli [47] is a designer who makes bioplastics in her studio: materials made of renewable natural resources, primarily waste products such as fruit skins, ashes, and fish scales, among others. According to a circular economy virtuous circle, the ingredients used in manufacturing are non-polluting, and at the end of their useful life, they are 100% compostable, leaving no residue. Bioplastics reduce environmental pollution. The benefits generated by replacing synthetic plastics with biodegradable ones are reflected in the planet we will leave to future generations. Her jewelry collection, Ode to Boys and Girls, is a series of happy pieces entirely made in bioplastics, like children's spirits when the conditions for such an environment are given.

The fourth scenario, "making in lab", can concern the world of jewelry in two aspects: the use of sustainable materials that "imitate" traditional ones and also their use not only in the jewelry product but in different phases, such as retail packaging. In light of global sustainability, studies are focusing on the creation of environmentally friendly, high-performance materials and on the optimization of production methods to minimize the use of resources and the introduction of harmful chemicals. The key to renewal is rooted in cross-disciplinary exploration, resulting from the mixture of expertise, sectors, and processes where ethics, science, and aesthetics come together to create something new but with a familiar form—as showcased by MycoFutures and in vitro meat.

Regarding jewelry, lab-grown diamonds are among the prominent topics generating interest in the sector. They are created in highly controlled laboratory environments using advanced technological processes that reproduce the conditions under which diamonds naturally develop when they form in the mantle beneath the Earth's crust. These labs create diamonds consisting of actual carbon atoms arranged in the characteristic diamond crystal structure. Since they are made of the same material as natural diamonds, they exhibit the same optical and chemical properties. Consumers are attracted to them as they do not lead to environmental degradation, and their production does not harm anyone. These are two pivotal considerations aligning with the 'responsible sourcing' trend that is gaining traction, especially among Gen-Z consumers. An illustrative example of the innovative use of lab-grown diamonds in jewelry is seen in the designs of Jony Ive and Marc Newson [48], who explore the possibilities offered by lab-grown diamonds, particularly in their form. Unlike natural diamonds, which are limited by their natural growth, lab-grown diamonds can be crafted into a variety of unique shapes and sizes, as dictated by design needs rather than natural formation. This flexibility allows us to imagine and design jewelry pieces that demonstrate a distinct fusion of art and science, harnessing the beauty of diamonds in shapes and forms previously unattainable with traditional diamond cutting techniques. Regarding packaging, some brands are already moving in this direction, trying to use sustainable materials as much as possible in the different stages of the supply chain. One example is Laura Elizabeth Jewelry [49]: this company uses recycled materials to create its jewelry and is committed to minimizing its carbon footprint using eco-friendly packaging

and reducing waste in its production processes, with all shipping and packaging made from recycled materials. All the case studies are shown in Figure 7.

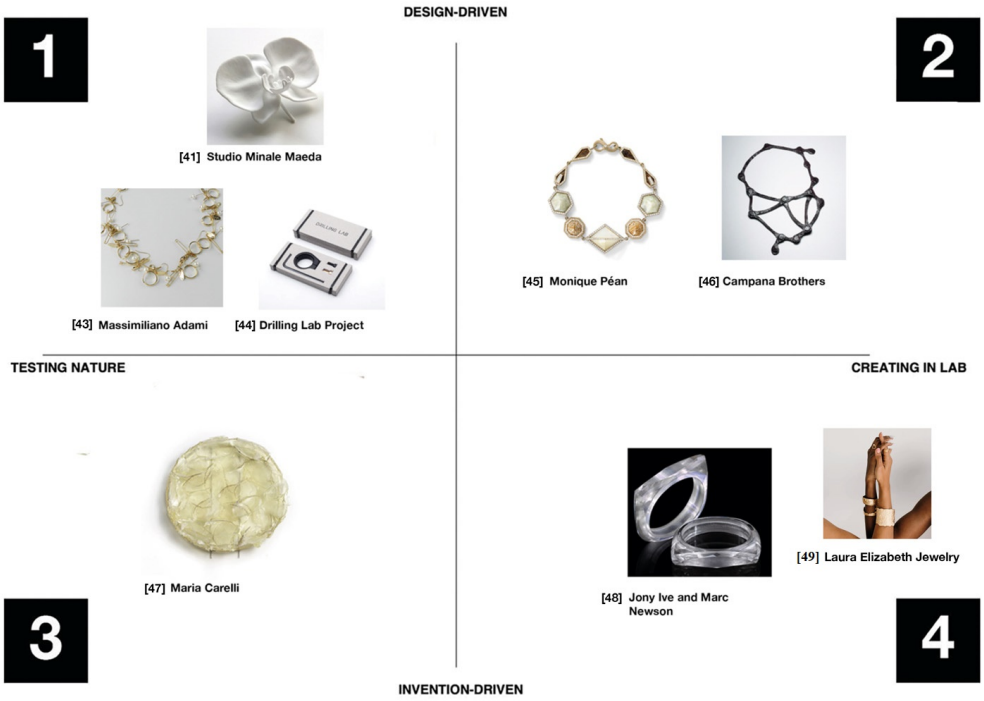

Figure 7. Coordinate plane and jewelry case studies. Studio Minale Maeda [41]; Massimiliano Adami [43]; Drilling Lab Project [44]; Monique Péan [45]; Campana Brothers [46]; Maria Carelli [47]; Jony Ive and Marc Newson [48]; Laura Elizabeth Jewelry [49]. Source: Authors.

As the scenarios and examples just mentioned show, the contribution of design is to intercept the changes taking place and provide sustainable responses. This means always being in tune with what is happening around us. For example, starting in 2030, about 5700 wind turbines made of carbon fibers will be dismantled each year in Europe alone, in addition to those in addition to those currently placed in landfills. Recycling composites is, therefore, becoming increasingly important and requires industrial choices and investment in research [50]. News that does not correlate with the jewelry world. However, could this not be a good opportunity? Could this not be a cue to think about limited edition products made from these materials that are valuable for the contribution they have made to the environment and can continue to make?

5. Conclusions

Many questions on this topic still remain unanswered, but this paper aims to provide a different perspective on finding opportunities in what already exists. As shown in Figure 8, this research identifies four future scenarios to set ourselves toward in the field of jewelry design. The first, "design sensibly", includes three directions: the possibility of designing using as few resources as possible ("litedesign"); design on request and involving the user who goes from consumer to prosumer ("instadesign"); design through the unit to facilitate the customization and adaptability of projects ("snapdesign"). The second scenario, "reshaping waste", traces two directions: the recycling of materials traditionally used in jewelry—such as gold and gems, for example ("likely"); the reuse of unconventional materials ("beyond"). The third scenario, "modeling nature", involves the use of materials of natural origin ("nature-crafted") and 100% compostable ("green-cycle") and favors the use of local raw materials and characteristics of the territory ("local-manufacturing"). Lastly, "making in lab" defines two paths: the creation of products using laboratory-grown materials that simulate materials traditionally used in jewelry—such as lab-grown

diamonds ("white Lie"); the use of laboratory-grown materials in packaging or products adopted at different stages of the supply chain ("besides").

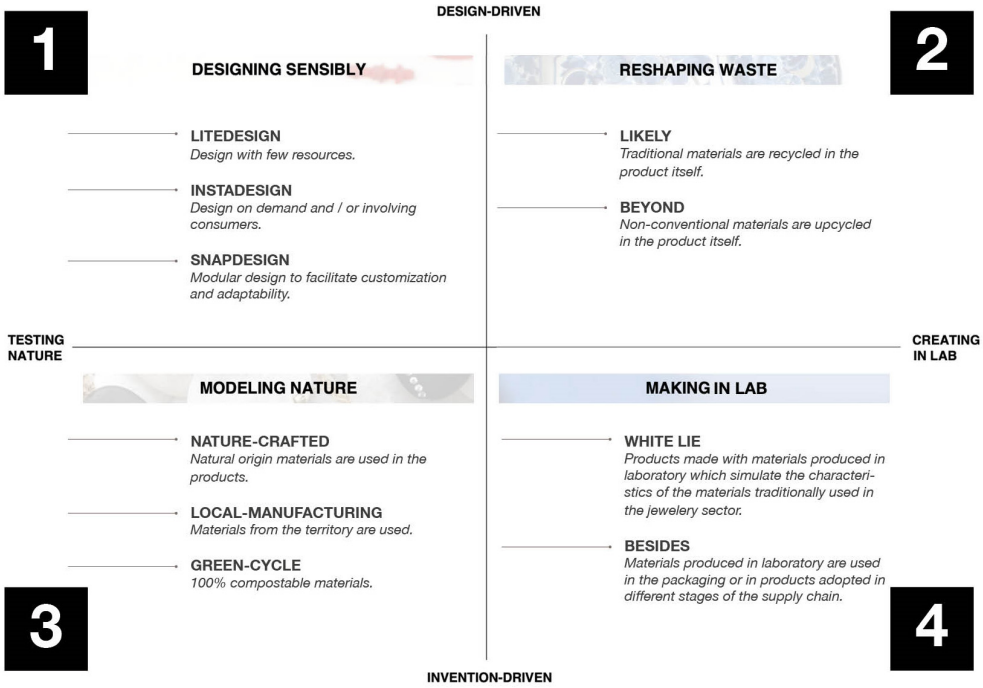

Figure 8. Scenarios and micro-scenarios for sustainable jewelry. Source: Authors.

This paper also highlights the importance of considering a process of cross-fertilization between different sectors and disciplines to create the most valuable innovations. As designers and companies working with the goal of sustainability, we must take into account not only the origin and properties of the materials we want to use or create but also the processes to obtain or transform them.

At the same time, it is fundamental to highlight that the discussion about the properties of materials to be used should be kept open for future debates. There are therefore important opportunities to explore, test, experiment, and patent new sustainable materials. Designers can lead this process, combining the technical and creative aspects of materials science to create more innovative and relevant products.

On one hand, it is very important to know the different offers of new sustainable materials and the related technologies and production processes. On the other hand, however, it is also necessary to start educating people on sustainability. Sustainability training is aimed at young students who will become the future experts of industries and companies, which are the main players today. The central point of this scenario is sustainability training. Design as a discipline should prepare people to use these new materials and processes to take full advantage of what science and different sectors are experimenting with. In conclusion, the role of education, carried out by universities and other education systems, must create and share knowledge on sustainability among students and company actors to raise awareness. Importance should be given not only to materials but, above all, to their uses.

Author Contributions: Conceptualization, L.T. and F.A.F.; methodology, L.T. and S.T.; validation, A.C.; investigation, F.A.F. and L.T.; resources, F.A.F.; data curation, F.A.F. and L.T.; writing—original draft preparation, F.A.F. and L.T.; writing—review and editing, L.T. and S.T.; visualization, F.A.F.; supervision, A.C.; reviews, L.T. and S.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Vezzoli, C. Sustainability and Discontinuity. In *Design for Environmental Sustainability*, 2nd ed.; Springer: London, UK, 2018; Volume 1, p. 4. [CrossRef]
2. Doordan, D.P. *On Materials*; The MIT Press: Cambridge, MA, USA, 2003; Volume 19, pp. 3–8.
3. Vezzoli, C. The "Material" Side of Design for Sustainability. In *Materials Experience: Fundamentals of Materials and Design*; Butterworth-Heinemann: Oxford, UK, 2013; pp. 105–121. [CrossRef]
4. Testa, S. Fashiontech. In *Body Equipment, Digital Technologies and Interaction*; Universitas Studiorum: Mantova, Italy, 2019.
5. Cappellieri, A.; Tenuta, L.; Testa, S.; Rossato, B. Future scenarios in Jewellery: Sustainability, innovation and challenges for the body at the Jewellery Museum. *Quad* **2022**, *5*, 253–264.
6. Manzini, E.; Jégou, F. *The Construction of Design Orientating Scenari*; Delft University of Technology: Delft, The Netherlands, 2000.
7. Conti, G.M. *Cross Fertilization: Un Approccio al Progetto per la Moda*; Mondadori Università: Milan, Italy, 2012.
8. Cappellieri, A. *Brilliant! The Futures of Italian Jewellery*; Corraini Edizioni: Mantova, Italy, 2016.
9. Shopping Bag by Lim Sungmook | DLS. Available online: https://www.dls.world/ (accessed on 19 October 2023).
10. Demetra by Gucci. Available online: https://www.gucci.com/it/it/ (accessed on 19 October 2023).
11. 3D Floors by Aectual. Available online: https://www.aectual.com/ (accessed on 19 October 2023).
12. Toilet Constructions by Ruhani Verma. Available online: https://archello.com/brand/rd-studio (accessed on 19 October 2023).
13. Coffee Mugs by Repulp Design. Available online: https://repulp.fr/ (accessed on 19 October 2023).
14. Acoustic Panels Indigo by Studio Flaer. Available online: https://www.studioflaer.com/ (accessed on 19 October 2023).
15. Furnitures by Philippe Tissot and YuTyng Chiu. Available online: https://komut.studio/ (accessed on 19 October 2023).
16. AltMat. Upgrading Agriculture Waste into Natural Materials. Available online: https://altmat.in (accessed on 19 October 2023).
17. Sacalho Tote Bag by Gui Giantini. Available online: https://www.guigiantini.com/ (accessed on 19 October 2023).
18. Ocean Bound Plastic by #tide. Available online: https://www.tide.earth/en/ (accessed on 19 October 2023).
19. Arda, Material Innovation Backed by Science. Available online: https://www.arda.bio/ (accessed on 4 January 2024).
20. Deserttex by Adriano di Marti. Available online: https://desserto.com.mx/adriano-di-marti-1 (accessed on 19 October 2023).
21. Ohoskin. Available online: https://www.ohoskin.com/ (accessed on 19 October 2023).
22. Seashell Material by Ostrea Design. Available online: https://www.ostreadesign.com/ (accessed on 19 October 2023).
23. Seaweed Material by Carbonwave. Available online: https://carbonwave.com/ (accessed on 19 October 2023).
24. Slowhide by Slow Factory Labs. Available online: https://slowfactory.earth/ (accessed on 19 October 2023).
25. CleanCloud by Borealis. Available online: https://www.borealisgroup.com/ (accessed on 19 October 2023).
26. Nakedpak by Naama Nicotra. Available online: https://naamanicotra.com/nakedpak (accessed on 19 October 2023).
27. Mycelium Material by MycoFutures. Available online: https://www.myceliumofthefuture.com/ (accessed on 19 October 2023).
28. Lab Grown Leather by Faircraft. Available online: https://www.faircraft.bio/ (accessed on 19 October 2023).
29. Biopuff by SaltyCo. Available online: https://www.ponda.bio/ (accessed on 19 October 2023).
30. Ellen Macarthur Foundation. Available online: https://www.ellenmacarthurfoundation.org/news/an-introduction-to-circular-design (accessed on 19 October 2023).
31. Chamorro-Mera, A.; Robina-Ramírez, R. Green Is in Fashion: Eco-Design and Circular Economy Strategies in the Fashion Industry. In *Responsible Consumption and Sustainability*; Bianchi, E.C., Vazquez Burguete, J.L., Galan-Ladero, M.M., Lanero Carrizo, A., Eds.; Springer Business Cases; Springer: Cham, Switzerland, 2023. [CrossRef]
32. Dokter, G.; Thuvander, L.; Rahe, U. How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy. In *Sustainable Production and Consumption*; Elsevier: Amsterdam, The Netherlands, 2021; Volume 26, pp. 692–708. ISSN 2352-5509. [CrossRef]
33. Helbig, C.; Huether, J.; Joachimsthaler, C.; Lehmann, C.; Raatz, S.; Thorenz, A.; Faulstich, M.; Tuma, A. A terminology for downcycling. *J. Ind. Ecol.* **2022**, *26*, 1164–1174. [CrossRef]
34. Fahmi Hussein, J.M. The Ideal Usage of Sustainable Materials and Local Resources of the Interior Space Design. *J. Civ. Eng. Archit.* **2012**, *6*, 1047–1058. [CrossRef]
35. Benefits of Using Recycled Materials: A Guide For Building Professionals. Available online: https://ugreen.io/benefits-of-using-recycled-materials-a-guide-for-building-professionals/#:~:text=Reduced%20Resource%20Extraction:%20Recycling%20reduces,the%20production%20of%20new%20materials (accessed on 19 January 2024).
36. Kandachar, P. Materials and social sustainability. In *Materials Experience: Fundamentals of Materials and Design*; Karana, E., Pedgley, O., Rognoli, V., Eds.; Delft University of Technology: Delft, The Netherlands, 2014; p. 99. [CrossRef]
37. Liu, A.P.; Appel, E.A.; Ashby, P.D.; Baker, B.M.; Franco, E.; Gu, L.; Haynes, K.; Joshi, N.S.; Kloxin, A.M.; Kouwer, P.H.J.; et al. The living interface between synthetic biology and biomaterial design. *Nat. Mater.* **2022**, *21*, 390–397. [CrossRef] [PubMed]

38. Tang, T.C.; An, B.; Huang, Y. Materials design by synthetic biology. *Nat. Rev. Mater.* **2021**, *6*, 332–350. [CrossRef]
39. Baharom, M.Z.; Delbressine, F.; Toeters, M.; Feijs, L. The Design Evolution of the Zipper: A Patent Review. In Proceedings of the ICIBE'18: 4th International Conference on Industrial and Business Engineering, Macao, China, 24–26 October 2018; pp. 288–294. [CrossRef]
40. Cappellieri, A. *Twentieth-Century Jewellery: From Art Nouveau to Contemporary Design in Europe and the United States*; Skira: Milan, Italy, 2010.
41. Studio Minale Maeda. Available online: https://www.minale-maeda.com/CHP-ORCHID (accessed on 19 October 2023).
42. Cappellieri, A.; Tenuta, L.; Testa, S. Jewellery between Product and Experience: Luxury in the Twenty-First Century. In *Sustainable Luxury and Craftsmanship*; Gardetti, M.A., Coste-Manière, I., Eds.; Springer: Singapore, 2020. [CrossRef]
43. Massimiliano Adami. Available online: http://www.massimilianoadami.it/molecole-preziose.html (accessed on 19 October 2023).
44. Drilling Lab Project. Available online: https://www.drillinglab.com/ (accessed on 19 October 2023).
45. Monique Péan. Available online: https://www.moniquepean.com/ (accessed on 19 October 2023).
46. Campana Brothers. Available online: https://www.estudiocampana.com.br/ (accessed on 19 October 2023).
47. Maria Carelli. Available online: https://www.mariacarelli.com/ (accessed on 19 October 2023).
48. Jony Ive and Marc Newson. Available online: https://www.dezeen.com/2019/09/06/all-diamond-ring-jony-ive-marc-newson/ (accessed on 19 October 2023).
49. Laura Elizabeth Jewellery. Available online: https://lauraelizabethjewelry.com/ (accessed on 20 January 2024).
50. Sustainability Lab, Fibre di Carbonio più Sostenibili. Available online: https://sustainability-lab.net (accessed on 25 October 2023).

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.