MATERIAL INNOVATION INITIATIVE

2022 STATE OF THE INDUSTRY REPORT: NEXT-GEN MATERIALS

EXECUTIVE SUMMARY

This is the third State of the Industry Report: Next-gen Materials offered by the Material Innovation Initiative (MII). In 2022, similar to the preceding two years (2020 Report and 2021 Report), clear signals indicated the continuous acceleration of innovation, adaptation, and growth in next-gen materials.

This report will provide research, analysis, and insights to guide your understanding of the next-gen materials industry. Whether your interest is as an investor, entrepreneur or a member of a startup or brand, we have prepared this document to give you the most actionable information about the shift away from animal-based materials that is beginning to ripple through the fashion, automotive, and home goods industries.

Part A includes the **Introduction** and **Definition and Scope** that explains some key concepts and categorizations relevant to the next-gen materials industry. Our in-house experts also make Predictions on trends, risks, and opportunities.

In Part B, we introduce the three categories of key stakeholders in this industry, or **the three i's: Innovators, Investors, and Industry Brands**. Innovators are companies, including startups, that create innovative next-gen materials. **Investors** provide the necessary funding for innovators' R&D activities and business growth. **Industry Brands** are the established companies that are the biggest buyers and users of materials, such as Nike, IKEA, and BMW. Industry brands play multiple important roles in the ecosystem, including funding internal and external innovation initiatives, switching to next-gen materials as their raw materials, and collaborating with next-gen material startups to create new products. All this leads to the acceleration of commercialization and scale-up production of next-gen materials to replace their conventional counterparts.

Part C deep-dives into the most noteworthy industry topics. From growth bottlenecks to greenwashing, next-gen technologies to next-gen feedstocks to watch, we have **Real Talk** with experts and stakeholders to provide more context behind the data presented in Parts A and B.

SYLVEN NEW YORK

The Material Innovation Initiative (MII) is a nonprofit think tank that accelerates the development of high-performance, animal-free, and more sustainable materials for the fashion, automotive, and home goods industries. MII partners with startups, investors, brands, and scientists to bring these next-gen materials to market. Visit materialInnovation.org for more details.

STATE OF THE NEXT-GEN MATERIAL INDUSTRY AT A GLANCE

102 TOTAL NUMBER OF NEXT-GEN MATERIAL COMPANIES

64 LEATHER

15 SILK

10 WOOL

9 FUR

7 DOWN

1 EXOTIC SKINS

69 NEW COMPANIES FORMED SINCE 2013

OVER **$3 billion** INVESTED SINCE 2013

$457 million INVESTED IN 2022

$125 million LARGEST FUNDING ROUND 2022

117 UNIQUE INVESTORS IN 2022

$588 million TOTAL AMOUNT RAISED BY THE TOP FUNDED COMPANY

214 DEALS SINCE 2013

52% PLANT-DERIVED

19.6% MICROBE-DERIVED

8.8% BLENDS

8.8% MYCELIUM

6.9% RECYCLED MATERIAL

3.9% CULTIVATED ANIMAL CELLS

Exhibit 1. State of the next-gen material industry at a glance (2022)

Source: Material Innovation Initiative. All data as of Dec 31, 2022.
*Note: Some companies create more than one next-gen material.
**Note: To simplify the borad landscape of formulation and processing approaches for next-gen materials, MII categorizes next-gen innovation by main inpute (greater than 50%)

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Look for the IN logo throughout this report for next-gen material industry insights.

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PART A
TOWARDS NEXT-GEN

KINTRA FIBERS

1. INTRODUCTION

Conventional livestock-derived materials, such as leather, fur, silk, wool, down, and exotic skins, are widely used in the fashion, home goods, and automobile industries. Industrial animal farming is a leading cause of many of the pressing problems of our time, including climate change, environmental degradation, public health risks, and animal cruelty. It is a common misconception that animal-based materials are simply byproducts from industrial animal agriculture that primarily supplies to the food industry. Leather, for example, is the second most profitable product of a cow;[1] and for fur, silk, and exotic skins, the animal material itself is the most profitable product.

Adopting next-gen materials that are high-performance, animal-free, and environmentally preferred is key to shifting the world away from relying on unsustainable material supplies and practices.

While we saw an unprecedented spike in capital invested in next-gen materials companies in 2021, 2022 represented a more challenging funding environment for material innovators. As the world went through an economic downturn, the next-gen materials space was not immune to the adjustment. However, looking at the 10-year track from 2013 to 2022, both capital invested and number of deals continued their upward momentum.

The fashion world also went through a year of reckoning. 2022 will probably be remembered as the year of greenwashing crackdown in the fashion industry. This is the year when one of fashion's most adopted tools to measure the industry's environmental impact, the Higg Index, was paused for re-evaluation. Some predict that we will see less "sustainability marketing" until industry stakeholders have a better understanding and consensus regarding communicating with consumers on this sensitive and complicated subject.[2]

As the next-gen materials industry develops, and we offer you the third annual State of the Industry Report, we dig deeper into bottlenecks, pain points, and missed opportunities. Instead of tackling greenwashing with harsh social criticism, we look into creating industrial consensus on more standardized life cycle assessments (LCA) so stakeholders can improve on the scale of sustainability based on better data and science. We look into more case studies around the challenges of scaling up next-gen materials. There are many challenges; however, there are also many solutions. But understanding the nuances is the beginning of finding creative ways to overcome difficulties.

We continue to see significant demand for next-gen materials, but more supply is needed to meet the sustainability, performance, aesthetic, volume, and price needs of brands and consumers. In 2022, more established material companies, fashion houses, and even automotive manufacturers announced their next-gen material offerings or their in-house R&D to create next-gen materials. It is an encouraging signal that the next-gen materials industry has grown beyond the innovators disrupting the incumbents, but the established big players are also joining forces to create a better materials industry for all.

FORAGER

Expert Predictions

"Alternative proteins and precision fermentation will continue to expand to improve control of ingredient supply chains for various industries, from food and agriculture to materials and medicine."

David Kaplan
Advisor, Science and Technology Council, MII - Professor of Biomedical Engineering at Tufts University

"More notable investments from corporate venture arms of fashion houses and automotive groups into next-gen material startups."

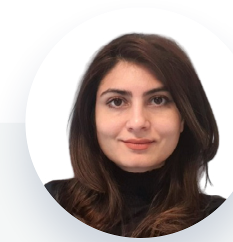
Elaine Siu
Chief Innovation Officer, MII

"Brands will offer more meaningful, sizable collections now as next-gen material companies come online and are ready for commercial scaling. Prices will start to come down for more accessibility and broader adoption."

Elissa Rosen
Chief Partnership Officer, MII

"With a tough economy and rising interest rates across the world, we expect a consolidation of the next-gen materials industry with more companies closing their doors than any other year."

Nicole Rawling
Co-founder & Chief Executive Officer, MII



"With the new wave of sustainability legislation, the media will have a sharper focus on the next-gen materials industry's claims on sustainability. All claims, from biodegradability to circularity, will be tested for greenwashing."

Pari Trivedi
Chief Communications Officer, MII

"Disclosure of environmental impacts related to material innovation and production shall be verified and integrated into decision-making frameworks to re-think fashion-related product level claims."

Ranjani Theregowda
Environmental Data Scientist, MII

"In a constrained funding environment, especially for earlier stage unproven models, next-gen materials companies will have to seek alternate sources of capital, be prepared for valuation haircuts or smaller rounds, and really focus on the differentiation of their technology and applications."

Siddharth Hariharan
Director, MII - Managing Director at Rothschild & Co

"Food, agriculture, and materials will become more intimately linked with more cross-industry research and collaboration in the bioeconomy."

Sydney Gladman
Chief Scientific Officer, MII

"We will see more brand experimentations with next-gen materials. It will move from hype to normal over the next five years."

Thomasine Dolan
Director of Materials & Design Innovation, MII

2. DEFINITION AND SCOPE

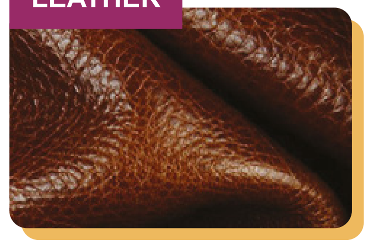
"Next-gen materials" are animal-free and environmentally preferable direct replacements for conventional animal-based leather, silk, fur, down, wool, and exotic skins (also referred to as "incumbent materials"). Next-gen materials use a variety of biomimicry approaches to replicate the aesthetics and performance of their animal-based counterparts.

Examples of exclusions from this definition include:

- materials that are not directly replacing animal-based materials;
- materials designed for use in construction, thermal cooling, and packaging solutions that traditionally do not make use of animal-based materials;
- recycling and upcycling technologies; wearable technologies, and
- dye, cut, trim, or other manufacturing and supply chain technologies.

"Current-gen materials" are those used to substitute for animal-derived materials by winning on price. For example, synthetic leather made from petrochemicals sells wholesale at one-third the cost of the animal leather equivalent. We generalize these petroleum-based alternatives (e.g., polyurethane (PU), polyvinyl chloride (PVC), acrylic fiber) as "current-gen materials," but their current applications in the market are far beyond animal-based material replacements. More clothing is made from polyester and nylon (both plastics) than cotton. Examples of "current-gen" alternatives include PU for leather, polyester for silk, and acrylic for wool.

LEATHER



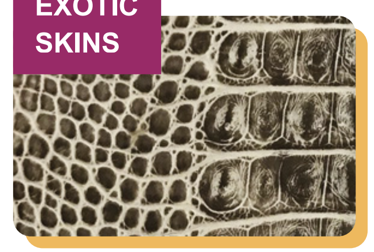
DOWN

SILK

WOOL

FUR

EXOTIC SKINS



ANIMAL-BASED
(INCUMBENTS)

Humans have used leather, silk, wool, fur, down, and "exotic" skins for centuries.

These animal-based materials present environmental and ethical challenges, which are increasingly urgent problems as the human population continues growing.

SYNTHETIC
(CURRENT-GEN)

The invention of synthetics in the 20th century enabled inexpensive petroleum-derived alternatives to animal-based materials: polyurethane, PVC, polyester, acrylic and more.

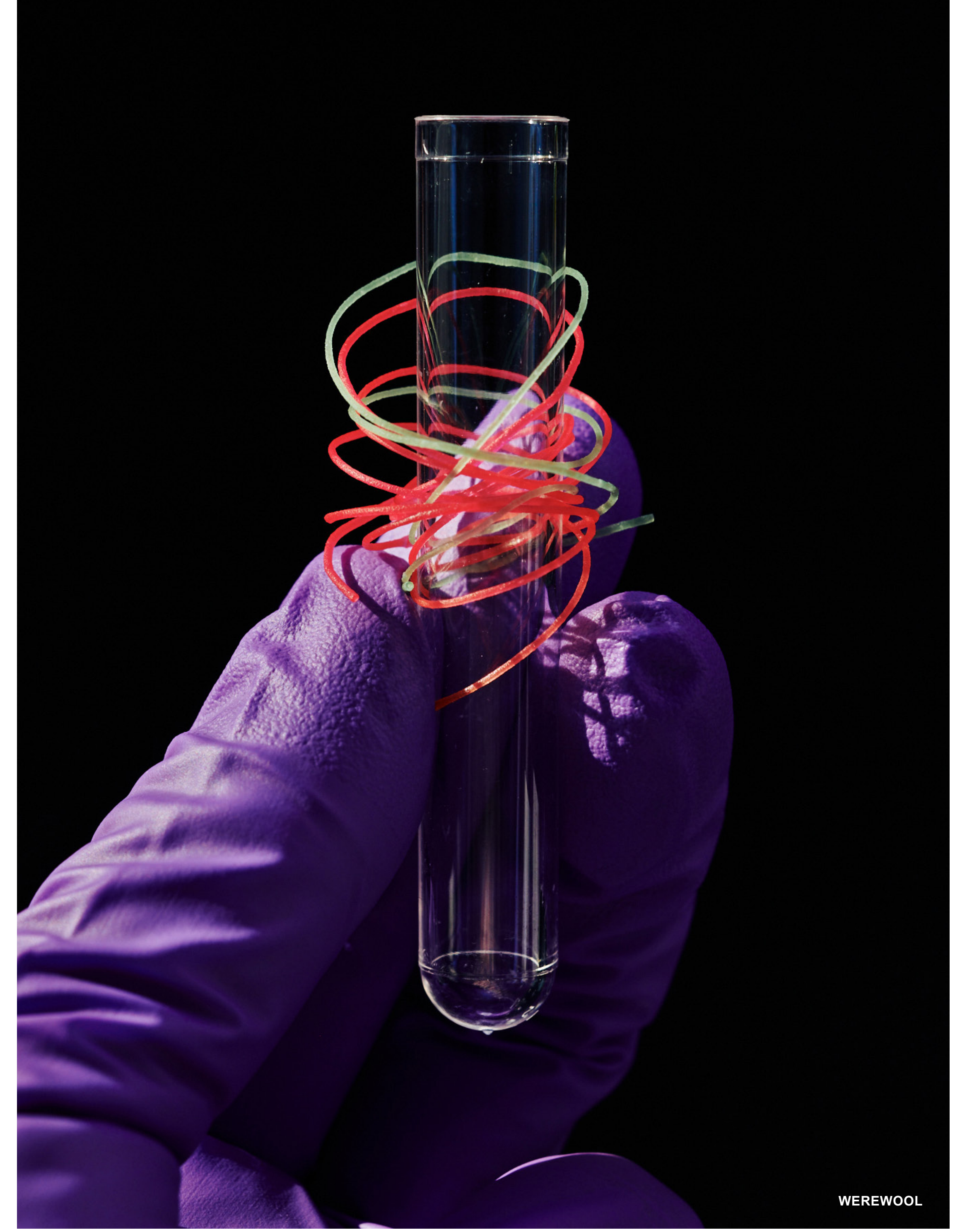
Unfortunately, these alternatives are also unsustainable and ethically fraught.

NEXT-GEN

A new crop of scientists, artists, and innovators are pioneering next-gen materials. These innovations are high performance, animal-free, and more sustainable.

This is the next generation of our material economy.

Exhibit 2. Incumbents, current-gen, and next-gen materials



"Disruptive textile technology" refers to technologies that are not specific to next-gen materials and, therefore, beyond the scope of this report. Synthetic materials are prevalent in today's world. Sustainable innovation in synthetics such as bio-based, biodegradable, and recycled polyester or polyurethane, and in sustainable renewable-sourced fibers such as cellulosics and natural fibers, could have a broad impact in the plastics and textiles industries as a whole and, in some cases, in the next-gen materials space. To the extent that these broad players and technologies may become promising feedstocks or resources for next-gen material innovation, MII has created a separate list of Disruptive Textile Innovation Resources to provide next-gen material innovators an easy way to find potential collaborators.

"Innovators, investors, and industry brands" refers to three groups of key stakeholders in the next-gen materials industry. The scope, definition, limitations, and assumptions underpinning the analysis of each stakeholder group are stated in each corresponding section in this report.

Main Input Categories

Not all next-gen materials are made using the same process or technology. We expect materials made from similar technologies to have similar advantages and disadvantages. To simplify the broad landscape of formulation and processing approaches for next-gen materials, MII categorizes next-gen innovation by main input (greater than 50%): plant-derived, mycelium, cultivated animal cells, microbe-derived, recycled material, and blend.

PLANT-DERIVED

Applies to next-gen materials derived from virgin or waste/byproduct plant matter. For simplicity, fungi (fruiting body) and algae inputs are included in this category, even though they are not plants.

MYCELIUM

Applies to next-gen materials that utilize the root-like structure of some fungal species called mycelium. This category is distinctive from the plant-derived category due to the rich activity of next-gen innovation involving mycelium.

CULTIVATED ANIMAL CELLS

Applies to next-gen materials that utilize tissue engineering approaches to grow animal cell constructs (e.g., skin) in the laboratory.

MICROBE-DERIVED

Applies to next-gen materials that utilize cellular engineering approaches such as cell culture or fermentation processes to produce products like proteins and biopolymers for next-gen material formulations.

RECYCLED MATERIAL

Applies to next-gen materials that utilize recycled plastic or recycled textile feedstock as a main input.

BLEND

Applies to next-gen materials that use a mixture of components not well-captured by any of the above categories.

As an example, Exhibit 3 below illustrates the variety of approaches for producing a next-gen material such as leather.

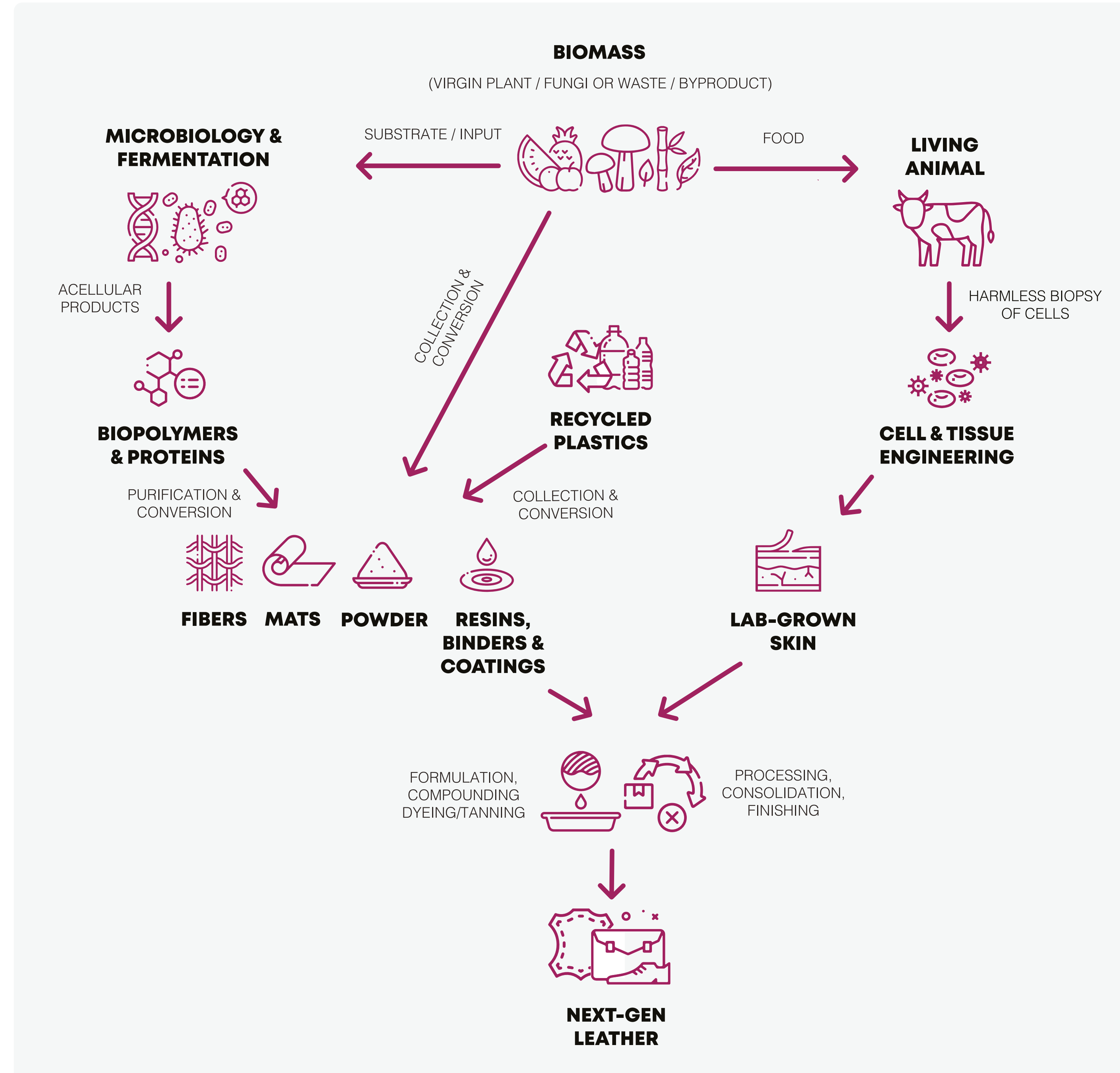


Exhibit 3. Conceptual landscape of next-gen leather materials

See other MII reports to learn more about next-gen materials science and engineering.

Please note that many material companies continually refine and update the formulations and technology behind their materials. At MII, we make every effort to keep up to date, especially on our website. This report represents the best information available at the time of publication.

PART B
KEY STAKEHOLDERS

IRENE VAN OPHOVEN X PIÑATEX

3. INNOVATORS

Overview

This section provides an overview of companies in the next-gen materials industry.

The innovator landscape continued to expand in 2022:
- At least five new next-gen material ventures were incorporated, out of 19 that have emerged and added to our database and analysis compared to the previous year.
- The number of companies focused exclusively on developing next-gen materials rose to 102.
- More and more material manufacturers, fashion conglomerates, and automakers have added next-gen materials to their offerings and/or publicly announced to be developing next-gen materials in-house. The number of such companies has risen to 20, listed in Exhibit 8.

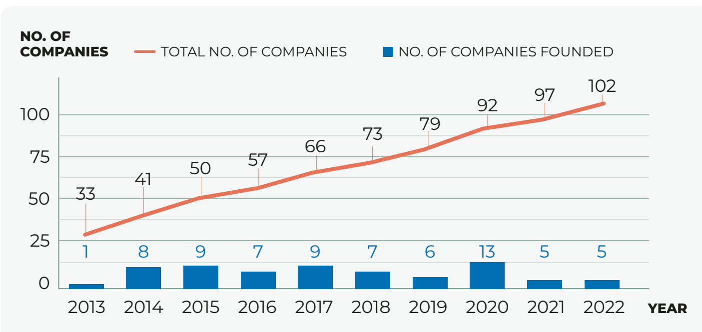


Exhibit 4. Numbers of companies by year founded

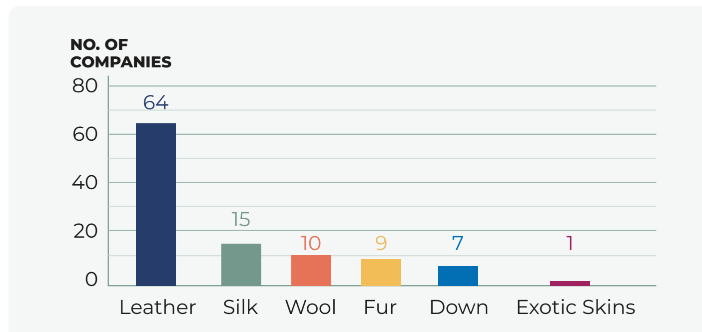


Exhibit 5. Number of companies by type of next-gen material

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Having tracked material innovators for a few years now, it has become clear to us that many of them may choose to stay in stealth mode until they are ready to launch.

Therefore, while this report covers 5 ventures formally incorporated in 2022, our analysis also covers an additional 19 startups and 4 corporations that emerged over 2022 to disclose their activities in next-gen materials publicly.

*Out of the 5 new next-gen material ventures, 3 work in next-gen leather (**Arda Biomaterials** and **Really Clever** are based in the UK and **ATMA Leather** from India), 1 works in next-gen fur (**BioFluff** from the US), and 1 in next-gen wool (**ESG Brands** from the US).*

*Three corporations have also announced to be developing their own next-gen leather; they are **Gucci**, **Volkswagen**, and **Volvo**, while **Pangaia Grado Zero** is also developing a next-gen leather material as well as a next-gen down.*

IN

*Of the 102 companies, the majority (64) work on biomimicry of animal leather. Fifteen (15) work on biomimicry of silk, ten (10) on wool, nine (9) on fur, seven (7) on down, and one (1) on exotic skins.**

Over 60% of current players in the next-gen materials industry target next-gen leather, leaving other categories such as silk, wool, down, fur, and exotic skins with limited innovation efforts.

In particular, silk, fur, and exotic skins are attractive for early-stage innovators. High-value product targets could enable a faster path to price parity than commodity markets. For example, polyester yarn hovers around \$1/kg,[3] while raw silk averages around \$55/kg.[4] These underserved product categories currently mean a lack of competition, which may be attractive to innovators and investors looking to enter the next-gen materials industry.

**Some companies work on more than one replacement of animal-based materials. Some next-gen material companies market their material as next-gen rather than as a next-gen replacement for a specific animal material. This report places the material in a next-gen category according to its primary application in end products*

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"I had the pleasure of examining next-gen materials from over 40 innovators over the last two years. Half of them started less than three years ago. 90% of them are working on replacing animal leather. Early next-gen leather swatches frequently have performance issues: microbubbles, irregular color, scratchable surface, water repellency, and tearing. In addition to tackling these problems, they are also experimenting with whether or not to have a textile backing, which can present adherence issues but does improve tensile strength.

On top of these challenges, everyone's goal is to get to a point where they do not need to use PU—which is the performance enhancer for current/incumbent synthetic leathers as well as the magic ingredient for the majority of animal leather where it is used to protect color and surface integrity. These material innovators are really brave pioneers seeking to re-invent how things have been done for decades.

I have found that the companies making the fastest progress have 1-2 scientists on the team and someone with a good business head and a heavy-duty belief system! The other scenario is to have someone from the traditional textile world team up with a material scientist. This combination works because one person understands existing manufacturing technology—the goal is 'plug and play' for many of these materials—and the other person brings knowledge of green chemistry and technology.

It was particularly exciting to meet makers and see their swatches in other categories this year. I worked closely with a company that makes an incredibly soft 'vegetable cashmere' they will be selling as a yarn as well as cut and sew knits. Another maker uses bamboo to weave soft-as-silk (yes, it has a sheen) fabric and offers a brushed woven "cashmere." And one of the most exciting new start-ups (less than two years old) is making the fluffiest, multi-length, the world's first 100% plant-based, silky fur made from agricultural waste.

I feel that 2023 will yield more innovators in these non-leather spaces as many were in stealth mode in 2022."

Thomasine Dolan
Director of Materials & Design Innovation, Material Innovation Initiative

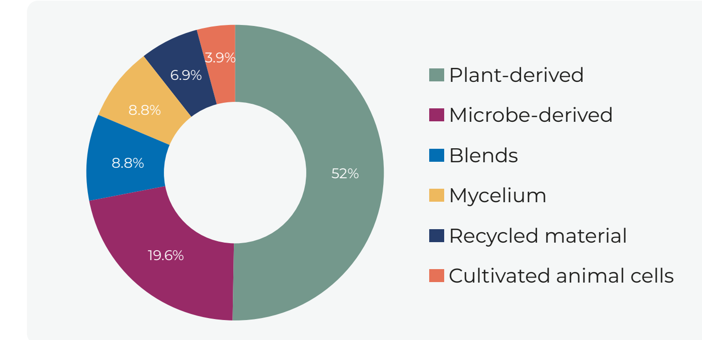

Exhibit 6. Numbers of companies by main input and technology

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Although next-gen materials are commonly associated with using plants and plant-derived materials as a main input, many different technologies and inputs are part of reimagining next-gen materials.

Of the 102 next-gen material companies listed below, while a majority (53) use plant-derived materials as main input, twenty (20) use microbe-derived materials, nine (9) use blends, nine (9) use mycelium, seven (7) use recycled material, and four (4) use cultivated animal cells.

Material innovators employ a variety of inputs and technology to create materials that range from mats to fibers to insulating fluff. Some technologies allow a company to achieve diverse biomimicry and applications.

The feedstock, main input, and technologies employed can significantly impact product aesthetics, performance, time, and scale-up cost. This will be covered in more detail in section 7 (Less Starting Up, More Scaling Up).

Argentina	1	Finland	2	Peru	1
Australia	2	France	2	Phillippines	1
Belgium	1	Germany	7	Poland	1
Brazil	2	Indonesia	1	Puerto Rico	1
Canada	3	India	6	Spain	2
Chile	1	Israel	1	Sweden	1
China	2	Italy	9	Switzerland	1
Columbia	1	Japan	1	Turkey	2
Costa Rica	1	Mexico	2	Ukraine	1
Denmark	1	Netherlands	5	Utd. Kingdom	7
				Utd. States	30

Exhibit 7. Numbers of companies by country

The list focuses on known companies that innovate in next-gen materials. Not included are business-to-consumer companies that do not develop and create their materials but source instead from a material supplier, R&D happening within corporations that is not publicly disclosed, startups in stealth mode, and any other material innovations that do not fall within the definition of next-gen materials as defined in section 2 (Definition and Scope).

Exhibit 8. Next-gen material innovators (in alphabetical order)

Company name	Material name(s)	HQ	Founders	Year founded	Biomimicry	Main input
Adriano di Marti	Desserto®, Deserttex®	MEX	Adrián López Velarde, Marte Cázarez	2019	Leather	Blend
● **AltMat**	Altag	IND	Shikha Shah	2019	Wool, Fur	Plant-derived
Amadeu		BRA	Flavia Amadeu	2016	Leather	Plant-derived
AMSilk	Biosteel®	DEU	Thomas Scheibel	2008	Silk	Microbe-derived
Ananas Anam	Piñatex®	GBR	Dr. Carmen Hijosa	2011	Leather	Plant-derived
● **Arda Biomaterials**	New Grain™	GBR	Edward Mitchell, Brett Cotten	2022	Leather	Plant-derived
● **ATMA Leather**		IND	Jinali Mody	2022	Leather	Plant-derived
Beyond Leather	Leap™	DNK	Hannah Michaud, Mikael Eydt	2016	Leather	Plant-derived
BioFabbrica LLC (affiliated with Modern Meadow)		USA	Andras Forgacs, Gabor Forgacs, Karoly Jakab, Francoise Marga	2011	Leather	Plant-derived
● **BioFluff**	BioFluff®	USA	Ashwariya Lahariya, Martin Stüebler	2022	Fur	Plant-derived
Bioleather		IND	Pritesh Mistry	2019	Leather	Microbe-derived
Biophilica	Treekind™	GBR	Mira Nameth	2019	Leather	Plant-derived
Bolt Threads	Mylo™, Microsilk™	USA	Dan Widmaier, David Breslauer, Ethan Mirsky	2009	Leather, Silk	Mycelium, Microbe-derived
Bucha Bio	SHORAI™	USA	Zimri T. Hinshaw	2020	Leather	Plant-derived
Carbonwave (previously known as C-Combinator)		PRI	Geoff Chapin, Ben Ellis	2020	Leather	Plant-derived
Coronet	BioVeg, Maison, Innovaction	ITA	Enrico De Marco	1966	Leather	Blend
Culthread		GBR	Rina Einy	2018	Fur	Recycled material
Devo Home		UKR	Oksana Devoe	2008	Fur	Plant-derived
Eco Vegan Leather Private Limited	Ultraw Vegan Leather	IND	N/A	2021	Leather	Plant-derived
Ecopel	KOBA® Faux fur, Cannaba Wool, GACHA-Fur	CHN	Christopher Sarfati	2003	Fur	Blend
EcoSimple		BRA	Cláudio Rocha, Marisa Ferragutt	2010	Wool	Recycled material
EcoSupreme		USA	Ivan (Hui) Wang	2008	Down	Microbe-derived
Ecovative	MycoFlex™, Forager™ Hides	USA	Gavin McIntyre, Eben Bayer	2007	Leather	Mycelium
ENKA		POL	Parent Company: International Chemical Investors Group	1924	Silk	Plant-derived
● **Evrnu**	NuCycl™	USA	Stacy Flynn, Christopher Stanev	2020	Silk	Recycled material
● **ESG Brands**	BANEX	USA	Chase Kahmann, Gavin Pechey, Ryan Bachman, Ravi Kallayil	2022	Wool	Plant-derived
Ettitude	CleanBamboo™	USA	Phoebe Yu	2014	Silk	Plant-derived
Faborg	Weganool™	IND	Shankar Dhakshinamoorthy	2015	Wool	Plant-derived
Faircraft		FRA	Haïkel Balti, Cesar Valencia Gallardo	2020	Leather	Cultivated animal cells
Fiquetex		COL	Alejandro Moreno, Gabriel Moreno	2017	Leather	Plant-derived
Flocus		NLD	Jeroen Muijsers	2014	Down	Plant-derived
Flora Fur		USA	Isabella Bruski, Noah Silva	2018	Wool	Plant-derived
Fruitleather Rotterdam		NLD	Koen Meerkerk, Hugo de Boon	2016	Leather	Plant-derived
Fruitonauts						
Frumat	Appleskin™	ITA	Hannes Parth	2008	Leather	Blend
GeneUs Biotech (previously known as Furoid)	LIQUIDWOOL™	NLD	Maria Zakurnaeva, Henri Kunz	2017	Fur, Wool	Cultivated animal cells
● **Gozen Institute**	Xylozen™	TUR	Ece Gözen Akın	2020	Leather	Microbe-derived
Gunas New York	Mulbtex™	USA	Sugandh G. Agrawal	2009	Leather	Plant-derived
Hemp Black	HEMP BLACK™/hide	USA	N/A	2017	Leather	Blend
House of Fluff	BIOFUR™	USA	Kym Canter	2017	Fur	Blend
Jacinto & Lirio		PHL	Anne Mariposa-Yee, Noreen Bautista, Patricia Lalisan, Ryan Pelongco, and Charm Cruz	2009	Leather	Plant-derived
KD New York	Vegetable Cashmere	USA	David Lee, Tricia Kaye	1980	Wool	Plant-derived
KeelLabs (previously known as AlgiKnit)		USA	Tessa Callaghan, Aleks Gosiewski, Aaron Nesser	2017	Silk	Plant-derived
Le Qara		PER	Jacqueline L. Cruz, Isemar Cruz	2017	Leather	Microbe-derived
● **LOVR**	LOVR	DEU	Montgomery Wagner, Julian Mushövel, Lucas Fuhrmann	2021	Leather	Plant-derived
Luckynelly	Berriestex, Citrustex	DEU	Christine Rochlitz	2012	Leather	Plant-derived
● **Metsä Spring Ltd.**	Kuura	FIN	N/A	2018	Fur, Wool	Plant-derived
Miko	Dinamica®	ITA	N/A	2015	Leather	Blend
MINK		USA	Rebecca Mink	2000	Leather	Plant-derived
Modern Synthesis		GBR	Jen Keane, Ben Reeve	2020	Leather	Microbe-derived
Mogu		ITA	Maurizio Montalti, Stefano Babbini, Federico Maria Grati	2015	Leather	Mycelium
MycaNova (Citribel)	MycaNova	BEL	N/A	1929	Leather	Plant-derived
MYCL - Mycotech Lab	Mylea™	IDN	Annisa Wibi, Adi Reza Nugroho, Ronaldiaz Hartantyo, Arekha Bentangan, Robby Zidna Ilman	2015	Leather	Mycelium
● **MycoFutures**	Mycelium-based material	CAN	Stephanie Lipp, Leo Gillis	2020	Leather	Mycelium
MycoWorks	Reishi™	USA	Philip Ross, Sophia Wang, Eddie Pavlu	2013	Leather	Mycelium
Mylium		NLD	Iris Houthoff	2018	Leather	Mycelium
● **Nanollose**	Nullarbor™	AUS	Wayne Best	2014	Silk	Microbe-derived
● **Napee**	Napee Vegan Leather	ITA	Alessandro Fabbri, Giuseppe Guido	2020	Leather	Plant-derived
Natural Fiber Welding	Mirum®	USA	Luke Haverhals	2015	Leather	Plant-derived
Newlight	AirCarbon™	USA	Kenton Kimmel, Mark Herrema	2003	Leather	Microbe-derived
NEXT-GEN LEATHER SL.	BacLEATHER™	ESP	Concha Garcia, L.A. Fernándes	2012	Leather	Microbe-derived
Nova Milan		CRI	Irma Orenstein, Karim Quazzani, Dror Weksler, Mycol Benhamou	2019	Leather	Plant-derived
NUVI Releaf		DEU	Nina Rössler	2014	Leather	Plant-derived
Ohoskin		ITA	Adriana Santanocito, CEO	2020	Leather	Plant-derived
Oleago	Oleatex™	TUR	Eşref Açık, Recep Eroğlu, Emre Eroğlu	2021	Leather	Plant-derived
Ono Collaborations		CHE	Bernadette Christina Bodenmueller	2017	Leather	Plant-derived
● **OPT Industries**		USA	Jifei Ou	2019	Down, Fur	Blend
Orange Fiber		ITA	Enrica Arena & Adriana Santanocito	2014	Silk	Plant-derived
Osom Brand	Osomtex®	USA	Patricia Ermecheo	2016	Wool	Recycled material
Panama Trimmings	Viridis®	ITA	Giuliano Pinato	1981	Leather	Plant-derived
Pangaia	FLWRDWN™	GBR	Jasmine Mullers, Rachna Bhasin, Nathalie Longuet	2018	Down	Plant-derived
PersiSKIN	PersiSKIN Vegan Leather	ESP	Jaime Sanfelix	2020	Leather	Plant-derived
Phool	Fleather	IND	Ankit Agarwal	2009	Leather	Microbe-derived
Polybion	Celium®	MEX	Axel Gómez-Ortigoza, Alexis Gómez-Ortigoza	2015	Leather	Microbe-derived
Provenance Bio		USA	Michalyn Andrews, Christian Ewton	2016	Leather	Microbe-derived
Proyecto Menos es Más	Bambuflex©	ARG	Natalia Pérez	2010	Leather	Plant-derived
Qorium		NLD	Rutger Ploem, Stef Kranendijk, Mark Post	2015	Leather	Cultivated animal cells
● **Really Clever**		GBR	Patrick Baptista Pinto, Matt Millar	2022	Leather	Mycelium
Renewcell	Circulose	SWE	Professor Mikael Lindström, Dr. Christofer Lindgren, Malcolm Norlin, Professor Gunnar Henriksson	2012	Silk	Recycled Materials
SaltyCo	BioPuff®	GBR	Julian Ellis-Brown, Antonia Jara-Contreras, Finlay Duncan	2020	Down	Plant-derived
Save The Duck	Plumtech®	CAN	Nicolas Bargi	2012	Down	Recycled material
ScobyTec	ScobyTec BNC	DEU	Carolin Wendel, Bernhard Schipper, Carolin Schulze	2014	Leather	Microbe-derived
Seevix Material Sciences	SVX™	ISR	Shlomzion Shen, Shmulik Ittah	2014	Silk	Microbe-derived
Slow Factory Labs	Slowhide	USA	Céline Semaan, Colin Vernon	2021	Leather	Microbe-derived
SmartFiber AG	SeaCell™, Smartcel™	DEU	Subsidiary of Lenzing AG	2005	Silk	Plant-derived
Soarce Boreas		USA	Mason Mincey, Derek Saltzman	2020	Leather, Wool	Plant-derived
Spiber	Brewed Protein™	JPN	Kazuhide Sekiyama, Sugawara Junichi	2007	Silk	Microbe-derived
Spidey Tek		USA	Roberto Velozzi	2015	Silk	Plant-derived
Spinnova		FIN	Juha Salmela, Janne Poranen	2014	Wool	Plant-derived
Spora Biotech	Sporatex	CHL	Hernán Rebolledo, José Miguel Figueroa	2017	Leather	Mycelium
● **Tandem Repeat**	Squitex	USA	Gozde Senel-Ayaz, Benjamin Allen, Melik Demirel	2018	Silk, Wool	Microbe-derived
Tenbro		CHN	N/A	2002	Silk	Plant-derived
The Center for Renewable Materials (UC San Diego)		USA	Anastasia Bachykala, Michael Burkart, Luca Bonanomi, Naser Pourahmady	2020	Leather	Microbe-derived
Ultrafabrics	Ultraleather® Volar Bio	USA	Clay Andrew Rosenberg & Barbara Danielle Boecker-Primack	1966	Leather	Blend
● **Uncaged Innovations**		USA	Stephanie Downs	2020	Leather	Plant-derived
Unreal Fur		AUS	Gilat Shan	2011	Fur	Recycled material
Vegea		ITA	Francesco Merlino, Gianpiero Tessitore, Valentina Longobardo	2016	Leather	Plant-derived
● **Vegeto**	Milkweed	CAN	Louis Bibeau	2018	Down	Plant-derived
VegSkin		FRA	Loïc Debrabander, Anaëlle Picavet	2020	Leather	Plant-derived
Vitro Labs		USA	Ingvar Helgason	2016	Leather, Exotic Skins	Cultivated animal cells
von Holzhausen	Banbū Leather, Technik-Leather	USA	Vicki von Holzhausen	2015	Leather	Plant-derived, Blend
Zvnder	Fungiskin	DEU	Nina Fabert	2017	Leather	Plant-derived

● Companies added to MII's Innovator Database in 2022

The next-gen materials industry and the innovators within this ecosystem develop quickly. All company references are purely illustrative. Please check our website for the latest company information. Apply to add new companies to our Innovator Database, or submit updates, here.

Exhibit 9. Corporations that have next-gen materials in their offerings

Company name	Material name	Headquarters	Biomimicry	Main input
3M	Thinsulate™ Insulation - Featherless	USA	Down	Recycled material
Asahi Kasei Corporation	Lamous, Bemberg™	JPN	Leather, Silk	Blend, Plant-derived
Eastman	Naia™	USA	Silk	Plant-derived
Fiscatech	Ultra Wer; Fly Tela Eco, Rinnova, E-ULTRA®	ITA	Leather	Blend; Plant-derived
General Silicones	Compo-SiL® (Vegan Silicone Leather, launched in 2018)	TWN	Leather	Blend
• **Gucci**	Demetra	ITA	Leather	Plant-derived
ISA TanTec	COSM™ (Creation of Sustainable Materials) - HyphaLite, VeraLite	MAC	Leather	Plant-derived
Jord	Suberhide™	USA	Leather	Plant-derived
Kuraray Co. Ltd.	CLARINO™ Sustainable Collection	JPN	Leather	Blend
Lenzing	Tencel™, Ecovero™	AUT	Down, Fur, Wool, Silk	Plant-derived
• **Pangaia Grado Zero**	Muskin™, BioGreen Padding	ITA	Leather, Down	Plant-derived
Paq Group International Ltd. - Vegetex	LorkApple	CHN	Leather	Plant-derived
Polartec	Power Fill™	USA	Down	Recycled material
PrimaLoft	PrimaLoft® Bio™	USA	Down	Recycled material
Sileather	N/A	USA	Leather	Blend
The LYCRA Company	THERMOLITE® EcoMade T-DOWN	USA	Down	Recycled material
Thermore	Ecodown®	NLD	Down	Recycled material
Toray Industries, Inc.	Ultrasuede®	JPN	Leather	Blend
• **Volkswagen**		DEU	Leather	Plant-derived
• **Volvo**	Nordico	SWE	Leather	Blend

• Companies added to MII's Innovator Database in 2022

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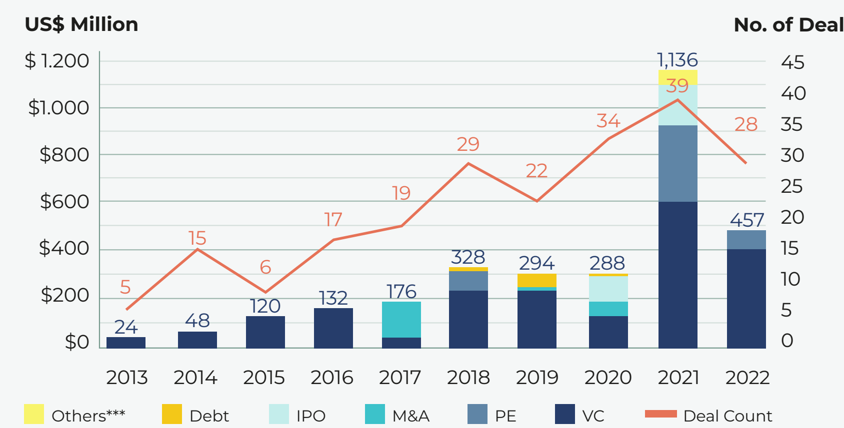
4. INVESTORS

Overview

This section provides an overview of investment activities in the next-gen materials industry.

The investment landscape continued to be active in 2022, despite the macroeconomic atmosphere:

- At least US$456.75 million was raised by the next-gen material companies listed in Exhibit 8 above from 28 publicly disclosed deals.
- In addition, there are many investment activities amongst corporations that have next-gen materials as part of their offerings and/or R&D. Most notably, the acquisition of The Lycra Company for US$1.573 billion in June 2022 by China Everbright Holdings Co., Lindeman Asia Investment, and Tor Investment Management. PrimaLoft was also acquired through a leveraged buyout for US$530 million in July 2022 by Compass Diversified, Victor Capital Partners, and its management.
- As of the end of 2022, we are aware of 20 next-gen material startups (these are in addition to the deals closed within 2022) actively fundraising. If you are an accredited investor, you may get access to active deal information by opting into [MII's Investor Database].



*** "Others" includes deal types (i) Secondary Transactions - Private, & (ii) Corporate (Non-control transaction)

Source: MII analysis on investment activities in companies included in MII's company database, based on data from PitchBook and primary research.

The data collected and analyses conducted are based solely on MII's company database (list of companies in Exhibit 8). The list of investors, investment figures, and other data are limited by publicly disclosed information. Since corporate R&D investment and other undisclosed deals are not included, the investment figures presented in this section, whether in relation to the industry or each company or investor, are likely underestimated.

All investment, investor, and company references are purely illustrative. Please note that the figures published in this report may differ from prior figures published by MII as we continually improve our dataset.

Exhibit 10. Number of companies by type of next-gen material

IN

In 2021, we saw an unprecedented spike in capital invested in next-gen materials companies, notable exits such as Spinnova's IPO accounted partly for the sharp increase. 2022 represented a more challenging investment atmosphere, and the next-gen materials space was not immune to the adjustment. However, looking at the 10-year track from 2013 to 2022, capital invested and the number of deals continued their upward momentum.

More notable funding in 2022 includes MycoWorks' US$125 million Series C closed in August, followed by a Series C2 closed in October 2022 estimated at US$63 million. Natural Fiber Welding (NFW) closed US$83 million Series B in April, followed by a debt financing of $19.97 million in December 2022. AlgiKnit also closed a US$15.46 million Series A funding round led by Collaborative Fund (also an investor in BOLT, NFW, and Modern Synthesis), which launched a new $200M climate-solution-focused fund with Stella McCartney this year. Cultivated leather startup VitroLabs secured Series A funding of US$47.40 million in May 2022; investors included global luxury fashion group Kering.

Save the Duck was also acquired for an undisclosed amount. Private equity fund Progressio SGR has controlled the company since 2018. L'Occitane Group chairman and CEO Reinold Geiger and André J. Hoffmann obtained majority ownership in 2022.

IN

"Given the way we define next-gen materials (animal-free and environmentally preferable direct replacements of conventional animal-based leather, silk, fur, down, wool, and exotic skins), we have been viewing the next-gen materials space with a keen reference to the alternative proteins industry. We see the next-gen materials industry as five to ten years behind alt proteins and the wholesale market size to reach $2.2 billion (USD) by 2026,[5] which was the approximate size of the alt proteins market back in 2019.

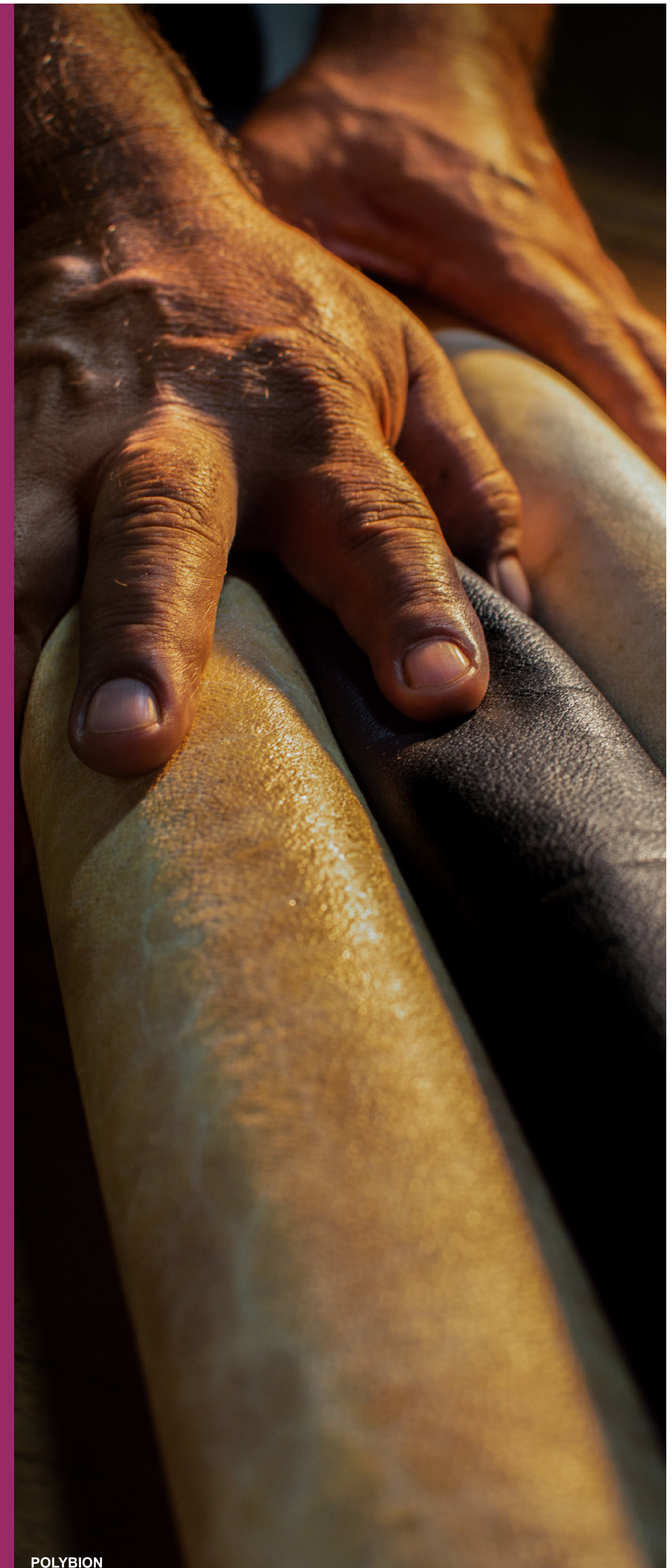
In 2022, after years of double-digit growth, the plant-based alternative meat market experienced stagnation. What does that mean for the next-gen materials space? What are the similarities and differences between the two industries relevant to our analysis of whether next-gen materials will continue to track alt proteins?

According to Deloitte,[6] on top of supply chain problems and tough comparison from impressive prior years of growth (sales of plant-based meat surged by 45% in 2020), 'the addressable market may be more limited than many thought.' Deloitte found that a shift in consumer sentiment around plant-based meat is one of the possible reasons behind a slowing demand.

When we look at the next-gen materials industry, one differentiation point is that the 'buyers' are not really the end consumer but companies such as fashion houses and automakers. The consumer buys the end product: a bag, a pair of sneakers, or a car, not a sheet of leather to sew a bag, make a shoe, or line the interior of a car. The decision-making process, and factors to consider, are very different from buying a food product. I know when I decide to buy a bag, it may be because it looks beautiful, its size and design suit my needs, I like the brand, and if it is also made with sustainable materials, that is great, but it's very unlikely for me to be buying a bag for the material(s) that it's made of (any end product is likely to be made by way more than one material anyway).

In the next-gen materials space, the buyers creating the demand more directly are the industry brands, the likes of Nike, IKEA, and Volvo, that purchase materials in thousands of tonnes per year. And what drives their demand for shifting from incumbent to next-gen materials is primarily the pressure upon them (including from consumers and regulations) to make progress in sustainability and decrease their environmental footprint. End consumers' sentiments matter, but the dynamics are very different compared to the food space."

Elaine Siu
Chief Innovation Officer, Materials Innovation Initiative



POLYBION

These investors invested in the next-gen material companies (listed in Exhibit 8) in the year of 2022 only. Only publicly disclosed information is included.

Exhibit 11. Investor in next-gen material companies in 2022

Investor	Investment Count (All Time)*	Investment Count (2022)*	Next-gen Material Companies Invested in	Investor Type	HQ Location
Collaborative Fund	7	3	Modern Meadow, Bolt Threads, Modern Synthesis, AlgiKnit, Natural Fiber Welding	Venture Capital	New York, NY
SOSV	7	2	MycoWorks, AlgiKnit, Bucha Bio, Gozen Institute	Venture Capital	Princeton, NJ
AgFunder	5	2	MycoWorks, Modern Synthesis, Mycotech Lab	Venture Capital	San Francisco, CA
Agronomics	5	1	VitroLabs	Venture Capital	Douglas, United Kingdom
Horizons Ventures	5	1	Modern Meadow, AlgiKnit	Venture Capital	Hong Kong, Hong Kong
Fashion For Good	4	3	AlgiKnit, Biophilica, Mycotech Lab	Accelerator/Incubator	Amsterdam, Netherlands
Hennes & Mauritz	4	1	Re:Newcell	Corporation	Stockholm, Sweden
Novo Holdings	4	1	MycoWorks, AMSilk	Venture Capital	Copenhagen, Denmark
Alwyn Capital	3	1	House of Fluff, Uncaged Innovations, Bucha Bio	Venture Capital	Brooklyn, NY
DCVC Bio	3	1	MycoWorks	Venture Capital	San Francisco, CA
Gaingels	3	1	MycoWorks, VitroLabs, Natural Fiber Welding	Venture Capital	Burlington, VT
IndieBio	3	1	MycoWorks, Bucha Bio, Biofluff	Accelerator/Incubator	San Francisco, CA
National Science Foundation	3	1	Ecovative, Natural Fiber Welding, Uncaged Innovations	Government	Alexandria, VA
Climate Capital	2	2	Modern Synthesis, Tandem Repeat	Venture Capital	San Francisco, CA
Lifely vc	2	2	Bucha Bio, Mycotech Lab	Venture Capital	Brazil
Social Starts	2	2	Biofluff, FairCraft	Venture Capital	San Francisco, CA
Vision Capital Group	2	2	MycoWorks, VitroLabs	Hedge Fund	Singapore, Singapore
Acequia Capital	2	1	Modern Synthesis	Angel Group	Seattle, WA
AiiM Partners	2	1	Ecovative, Natural Fiber Welding	Venture Capital	Palo Alto, CA
Alia Bhatt	2	1	Phool	Angel (individual)	
Beni Venture Capital	2	1	Bucha Bio	Venture Capital	Miami, FL
BMW i Ventures	2	1	Natural Fiber Welding	Corporate Venture Capital	Mountain View, CA
Central Illinois Angels	2	1	Natural Fiber Welding	Angel Group	Peoria, IL
Crosslink Capital	2	1	OPT Industries	Venture Capital	San Francisco, CA
E14 Fund Management	2	1	OPT Industries	Venture Capital	Cambridge, MA
Evolution VC Partners	2	1	Natural Fiber Welding	Venture Capital	New York, NY
Girincubator	2	1	Re:Newcell	Other	Stockholm, Sweden
Hemisphere Ventures	2	1	VitroLabs, MycoWorks	Venture Capital	Seattle, WA
IMO Ventures	2	1	Modern Synthesis	Venture Capital	Hong Kong, Hong Kong
Indian Angel Network	2	1	Phool	Angel Group	New Delhi, India
Khosla Ventures	2	1	VitroLabs	Venture Capital	Menlo Park, CA
Mirabaud Asset Management	2	1	Pangaia, MycoWorks	Asset Manager	London, United Kingdom
New Climate Ventures	2	1	Bucha Bio	Venture Capital	Houston, TX
Prithvi Ventures	2	1	Tandem Repeat, Bucha Bio	Venture Capital	New York, NY
Ralph Lauren	2	1	Natural Fiber Welding	Corporation	New York, NY
RebelBio	2	1	AlgiKnit	Accelerator/Incubator	London, United Kingdom
Regeneration VC	2	1	Pangaia, VitroLabs	Impact Investing	Los Angeles, CA
Spring Camp	2	1	Mycel Project	Venture Capital	Seoul, South Korea
Starlight Ventures	2	1	Modern Meadow, AlgiKnit	Venture Capital	Miami, FL
Swedbank Robur Fonder	2	1	Re:Newcell	Asset Manager	Stockholm, Sweden
Taihill Venture	2	1	Modern Synthesis	Venture Capital	Cambridge, MA
Third Derivative	2	1	Mycotech Lab	Accelerator/Incubator	Boulder, CO
We Ventures (Korea)	2	1	Mycel Project	Venture Capital	Seoul, South Korea
50 South Capital Advisors	1	1	Natural Fiber Welding	Fund of Funds	Chicago, IL
Advantage Capital (Saint Louis)	1	1	Natural Fiber Welding	PE/Buyout	Saint Louis, MO
Aqua-Spark	1	1	AlgiKnit	Venture Capital	Utrecht, Netherlands
Asymmetry Ventures	1	1	Bucha Bio	Venture Capital	San Francisco, CA
Ataraxia Capital Partners	1	1	Biofluff	PE/Buyout	Colombo, Sri Lanka
b.value AG	1	1	LOVR	Venture Capital	Dortmund, Germany
Beamline	1	1	Gozen Institute	Accelerator/Incubator	Tallinn, Estonia
Blue Wire Capital	1	1	FairCraft	Venture Capital	London, United Kingdom
BMH Beteiligungs-Managementgesellschaft Hessen	1	1	LOVR	Venture Capital	Wiesbaden, Germany

Bridge Capital Holding	1	1	OPT Industries	PE/Buyout	Beirut, Lebanon
Chris Zarou	1	1	Bucha Bio	Angel (individual)	
Cliens Kapitalförvaltning	1	1	Re:Newcell	Hedge Fund	Stockholm, Sweden
DCVC	1	1	MycoWorks	Venture Capital	Palo Alto, CA
Drive Catalyst	1	1	OPT Industries	Corporate Venture Capital	Taipei City, Taiwan
Engine No. 1	1	1	Natural Fiber Welding	Impact Investing	San Francisco, CA
Erin Culley	1	1	Biofluff	Angel (individual)	
ForGood (VC)	1	1	Piñatex	Venture Capital	London, United Kingdom
Gerry Murfitt	1	1	Biofluff	Angel (individual)	Walnut, CA
Gianluca Gera	1	1	Biofluff	Angel (individual)	
GlassWall Syndicate	1	1	Bucha Bio	Other	Leawood, KS
GM Ventures	1	1	MycoWorks	Corporate Venture Capital	
Good Startup	1	1	VitroLabs	Venture Capital	Singapore, Singapore
Greentown Labs	1	1	Bucha Bio	Accelerator/Incubator	Somerville, MA
Grit Ventures	1	1	OPT Industries	Venture Capital	San Mateo, CA
GROW accelerator	1	1	Mycotech Lab	Accelerator/Incubator	Singapore, Singapore
GSB Impact Fund	1	1	AlgiKnit	Impact Investing	Stanford, CA
H&M CO:LAB	1	1	AlgiKnit	Corporate Venture Capital	Stockholm, Sweden
HackCapital	1	1	Tandem Repeat	Venture Capital	Lausanne, Switzerland
Handelsbankens Fondbolagförvaltning	1	1	Re:Newcell	Corporation	Stockholm, Sweden
HEAG Holding	1	1	LOVR	Corporation	Darmstadt, Germany
Hico Capital	1	1	MycoWorks	Corporate Venture Capital	Palo Alto, CA
Hyundai Motor Securities	1	1	Mycel Project	Investment Bank	Seoul, South Korea
Industrial Bank of Korea	1	1	Mycel Project	Corporation	Seoul, South Korea
Invest FWD A/S	1	1	VitroLabs	Corporate Venture Capital	Aarhus, Denmark
Kering	1	1	VitroLabs	Corporation	Paris, France
Korea Development Bank	1	1	Mycel Project	Investment Bank	Seoul, South Korea
Kube VC	1	1	VitroLabs	Venture Capital	United Arab Emirates
Leonardo DiCaprio	1	1	VitroLabs	Angel (individual)	Los Angeles, CA
Lewis & Clark AgriFood	1	1	Natural Fiber Welding	Growth/Expansion	Saint Louis, MO
Matthew Kellogg	1	1	Biofluff	Angel (individual)	
Milano Investment Partners	1	1	VitroLabs	Venture Capital	Milan, Italy
Mirae Asset Venture Investment	1	1	Mycel Project	Venture Capital	Seongnam City, South Korea
Mission and Market	1	1	VitroLabs	Angel Group	San Francisco, CA
New Agrarian Company	1	1	VitroLabs	Other	Douglas, United Kingdom
Northpond Ventures	1	1	OPT Industries	Venture Capital	Cambridge, MA
Paeonia Ventures	1	1	AlgiKnit	Family Office	Singapore, Singapore
Paul Foulkes	1	1	Biofluff	Angel (individual)	
Petri Bio	1	1	Modern Synthesis	VC-Backed Company	Torrance, CA
Pierre Denis	1	1	Modern Synthesis	Angel (individual)	New York, NY
Ponderosa Ventures	1	1	Modern Synthesis	Venture Capital	Vancouver, Canada
Possible Ventures	1	1	Modern Synthesis	Venture Capital	Munich, Germany
Prime Movers Lab	1	1	MycoWorks	Venture Capital	Jackson, WY
Raga Partners (New York)	1	1	Natural Fiber Welding	Venture Capital	New York, NY
REFASHIOND Ventures	1	1	Natural Fiber Welding	Venture Capital	New York, NY
Rhapsody Venture Partners	1	1	Biophilica	Venture Capital	Cambridge, MA
Rumah Group	1	1	Mycotech Lab	Venture Capital	
Saaristosaastopankki	1	1	Re:Newcell	Investment Bank	Nagu, Finland
Sand Hill Angels	1	1	Natural Fiber Welding	Angel Group	Mountain View, CA
Scrum Ventures	1	1	Natural Fiber Welding	Venture Capital	San Francisco, CA
Shanda Group	1	1	OPT Industries	PE/Buyout	Redwood City, CA
Sixth Sense Ventures	1	1	Phool	Venture Capital	Mumbai, India
SK Networks	1	1	MycoWorks	Corporation	
Stanford Graduate School of Business	1	1	AlgiKnit	Impact Investing	Stanford, CA
Stone Bridge Capital Management	1	1	Mycel Project	Hedge Fund	Bratislava, Slovakia
SV Pacific Ventures	1	1	MycoWorks	Family Office	San Francisco, CA
Tattarang	1	1	Natural Fiber Welding	Holding Company	Nedlands, Australia
Temasek Life Sciences Accelerator	1	1	Mycotech Lab	Accelerator/Incubator	Singapore, Singapore

The FSE Group	1	1	Piñatex	Venture Capital	Camberley, United Kingdom
Third Nature	1	1	AlgiKnit	Venture Capital	Ephrata, PA
Tidal Impact	1	1	Natural Fiber Welding	Impact Investing	San Francisco, CA
TLI Bedrock	1	1	Natural Fiber Welding	Hedge Fund	New York, NY
Unreasonable Capital	1	1	Natural Fiber Welding	Venture Capital	Boulder, CO
Ventech	1	1	FairCraft	Venture Capital	Paris, France
Zer01ne	1	1	Mycel Project	Accelerator/Incubator	Seoul, South Korea
Zimri Hinshaw	1	1	Biofluff	Angel (individual)	

Source: MII analysis on investment activities in companies included in MII's company database, based on data from PitchBook and primary research.

If you are an investor interested in the next-gen material industry, opt in to MII's Investor Database to receive deal flow updates.

The following are the 10 top-funded next-gen material companies listed in Exhibit 8, according to publicly disclosed data.

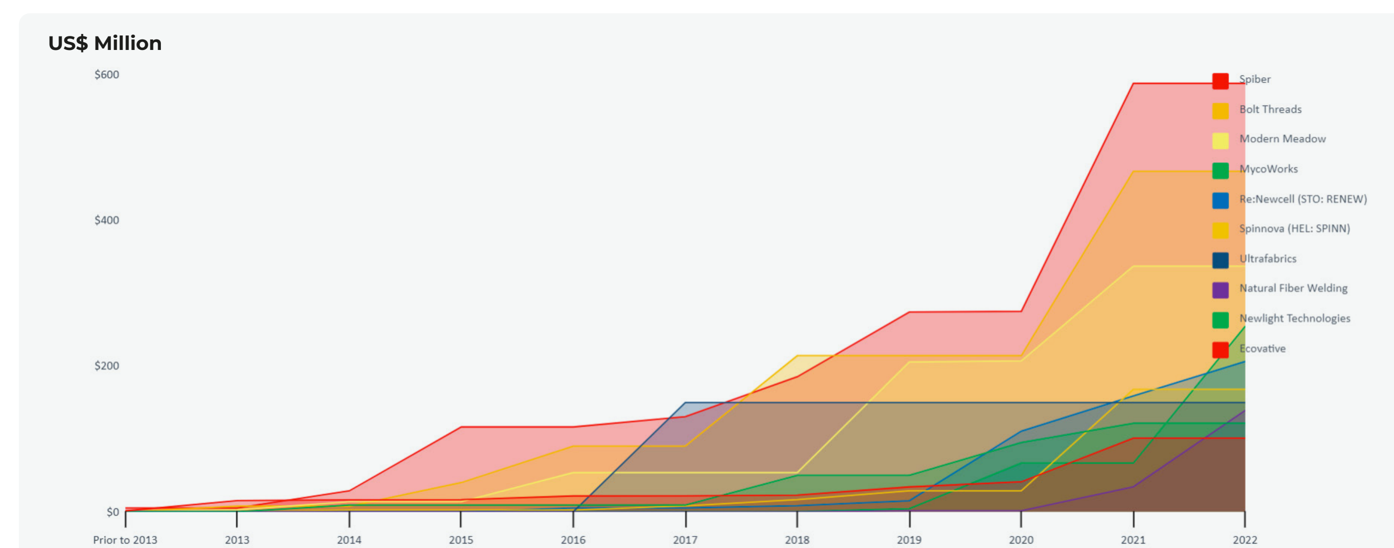
Exhibit 12. Top 10 most funded next-gen material companies (in descending order by total amount raised)

Company	Company Brief Description	Largest Round (USD million) / Date	Latest Round
Spiber	Produces spider silk proteins via precision fermentation to create next-gen silk primarily for the fashion industry. Collaboration with the designer Yuima Nakazato.	**313 / Sep 2021**	**PE Growth/Expansion**
Bolt Threads	Grows mycelium to produce next-gen leather and uses precision fermentation to produce spider silk proteins for next-gen silk. Both primarily target the fashion industry. Collaboration with Adidas, Kering, Lululemon, and Stella McCartney.	**253 / Sep 2021**	**Series E**
Modern Meadow*	Uses precision fermentation to grow collagen to create animal-free leather primarily for the fashion industry.	**151.74 / Sep 2019**	**Series C**
MycoWorks	Grows mycelium to produce next-gen leather primarily for the fashion industry. Collaboration with Hermès.	**125 / Jan 2022**	**Series C2**
Re:Newcell (STO: RENEW)	Renewcell's technology dissolves used cotton and other cellulose fibers. It transforms them into the biodegradable raw material (pulp) used by the textile industry to make viscose, lyocell, modal, acetate, and other types of regenerated fibers.	**95.51 / Nov 2020**	**PIPE**
Spinnova (HEL: SPINN)	Uses FSC-certified wood and waste streams to produce next-gen wool primarily for the fashion industry. Collaboration with Marimekko, H&M, Bergans of Norway, Bestseller (Fashion FWD).	**139.15 / Jun 2021**	**IPO**
Ultrafabrics	Ultrafabrics manufactures leather-free performance fabrics for a variety of applications in the automotive, aviation, health care, hospitality, and home goods industries.	**150 / Feb 2017**	**Merger/Acquisition**
Natural Fiber Welding	Uses fabricated compressed and/or discarded fiber sources coated with plant-based oil resin to produce next-gen leather primarily for the fashion industry. Collaboration with Allbirds, Ralph Lauren, Richemont, Melina Bucher, and others.	**85 / Apr 2022**	**Later Stage VC**
Newlight Technologies**	Uses natural ocean microorganisms to make PHB from greenhouse gasses to produce next-gen leather primarily for the fashion industry. Collaboration with Nike.	**45.13 / Sep 2020**	**Later Stage VC**
Ecovative	Grows mycelium on agricultural waste to produce next-gen leather, primarily for the fashion and self-care industries.	**60 / Mar 2021**	**Series D**

*Modern Meadow has formed a new joint venture BioFabbrica LLC with Limota, an Italian textile and materials supplier, to focus on developing next-gen leather.
**The total/cumulative amount raised neglects deals without a precise deal date. It underestimates the funding raised by Newlight Technologies, neglecting e.g., its series D (US$ 72.00M) and series E (US$ 36.80M) deals with undisclosed deal dates. Despite this, it is still ranked among the top 10 funded companies.

Source: MII analysis on investment activities in companies included in MII's company database, based on PitchBook and primary research data.

Exhibit 13. Funding history of top 10 funded next-gen material companies



*Company with one or more rounds of funding with undisclosed amounts. Undisclosed amounts have not been reflected in this figure.

Source: MII analysis on investment activities in companies included in MII's company database, based on PitchBook and primary research data.

5. INDUSTRY BRANDS

Overview

This section provides an overview of industry brands' involvement in the next-gen materials industry.

Partnerships between industry brands and material innovators continued to accelerate in 2022. A few highlights include:

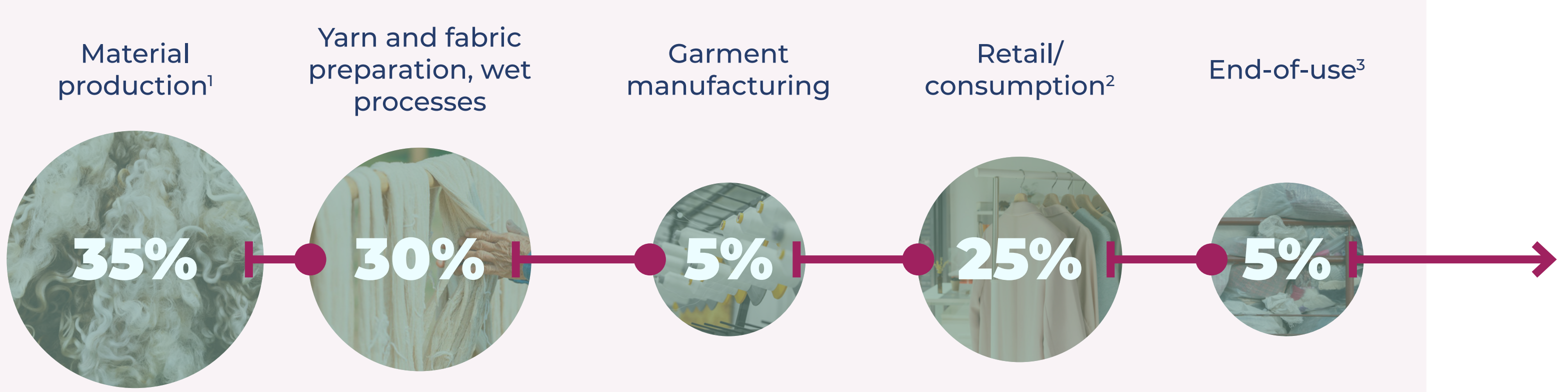
- In September, Allbirds released the Plant Pacer, a sneaker made with Natural Fiber Welding's (NFW) next-gen leather MIRUM®. Earlier in 2021, Allbirds invested $2 million in NFW, and in a year, we see the fruit of the culmination of the partnership between the two companies.
- In October, General Motors announced its investment, via its VC arm GM Ventures, in MycoWorks to secure joint R&D in an industrial partnership seeking to develop a mycelium animal-leather replacement that best suits the interiors of GM cars.
- In November, we saw a partnership that truly marries the two sides of the spectrum of incumbent and next-gen, tannery Ecco Leather—a company from Ecco Shoes—is working with Ecovative to create new leather-like alternatives. Ecovative, being a disruptor of the centuries-old leather market, demonstrates a unique opportunity of the newcomer working with the traditional.

Industry brands are established companies in fashion, automotive, and home goods that are the biggest buyers and users of materials. Although consumer preference has driven brands in these industries to move towards more sustainable practices, material innovators need a more direct relationship with consumers. The success of transitioning from animal-based materials to next-gen materials largely depends on innovators' ability to work with industry brands.

Industry brands can play multiple important roles in the ecosystem, including funding internal and external innovation initiatives, switching to next-gen materials as their raw materials, and collaborating with next-gen material startups to create new products. All this leads to accelerating commercialization and scale-up production of next-gen materials to replace their conventional counterparts.

MATERIAL PRODUCTION CREATES THE GREATEST CLIMATE IMPACT ACROSS THE FASHION LIFECYCLE

Relative climate impact across the major steps of the fashion lifecycle



1. Final output of the material production process is textile fibre. 2. Impact of microplastics is not considered in this impact size. 3. This does not include use in recycling process.

Source: The State of Fashion 2023, Business of Fashion - McKinsey & Company

Exhibit 14. Material production creates the greatest climate impact across the fashion lifecycle[19]

"Historically, tanneries have exclusively been associated with animal hides; with mycelium, this millennia-old industry can evolve, diversify and expand into a wider material market."

Bart Hofman-Kronborg, Group Manufacturing Director of Ecco Leather[1]

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*Across the fashion life cycle, 35% of climate impact originates from material production, and 30% comes from material preparation processes, i.e., the raw material bought by a fashion house already comes with **65% of climate impact**.*

Animal-based materials have some of the most significant adverse environmental impacts, whereas next-gen materials are poised to have lower environmental impacts than animal-derived materials and current-gen synthetics.

Many industry brands have specific, publicly disclosed targets and pledges to attain measurable improvements in sustainability. Given the significant impact raw materials have on a brand's environmental footprint, it is expected that these targets will be largely achieved through a transition from incumbent (and current-gen) materials to next-gen alternatives. These sustainability pledges, in terms of volume and timeline, are, therefore, a good reference for material innovators and investors to gauge the potential market size and growth rate of the next-gen materials industry.


TOM DIXON X PIÑATEX

Brands in fashion, automotive, and home goods are integrating next-gen materials into their products through partnerships, in-house innovation, investment, and advisory services. The Brand Engagement with Next-Gen Materials: 2022 Landscape report explains these strategies with over 140 examples involving these first-mover brands. To learn more about industry brands' engagement with next-gen materials, stay tuned for MII's following brand report (check for update releases here).

IN

"90% of the leading fashion brands MII has met with are exploring next-gen materials for new product development. Capsule collections, or at least including a couple of SKUs in next-gen materials, are becoming the norm. Brands getting in now will have an early advantage by strategically partnering with material companies while ultimately meeting the increasing consumer demand."

Elissa Rosen
Chief Partnerships Officer, Material Innovation Initiative


ALGIKNIT

First-Mover Brands

Creating with Next-gen Materials

A
adidas
Alexander McQueen
Alexandre Herchcovitch
Allbirds
Allégorie
Apparis
Arkimedia
Asics Corporation
Audi

B
Bellroy
Bentley
Bergans
Bestseller
Bleed
BMW

C
Capri Holdings Limited
Chicco
Coilex
Covalent
Cubus
Culthread

D
Disney
Dotz
Doublet
Dyne

E
E. Marinella
etéreo
Eva Klabalova & Lucie Trejtnarova

F
FAIRschuh
FitBit
Fossil
Fuchs Schmitt

G
Ganni
Genesis Footwear
Good Guys Don't Wear Leather
Gucci
Gus* Design Group

H
Hermès
Hilton
H&M
Horsefeathers
House of Fluff
Hugo Boss
Hyundai

I
iamoo
Infantium Victoria

J
Jacaranda
Jack & Jones
Jack Wolfskin
Jord

K
Karl Lagerfeld
Kazeto
Kering
Klättermusen
Komrads

L
Land Rover
Le Coq Sportif
Libena Rochova
Louis Vuitton
lululemon
Luxtra London

M
MA Allen Interiors
Maison Peaux Neuves
Marc O'Polo
Mārīcī
Marimekko
Marmot
Matt & Nat
Mercedes-Benz
Miomojo
Mochni
Modher
MoEa

N
Naot
Nike
Norrona

O
Oblique
Oroton
Other Stories

P
PANGAIA
Porsche
PVH

R
Ralph Lauren
Redemption
Reformation
Ricosta
Richemont
Roeckl
Roman Raibaudi

S
Salvatore Ferragamo
Samara
Sanabul
Save The Duck
Saye
Serapian
Skagen
Stella McCartney
Stüssy
Sylven New York

T
Timberland
Thayer Coggin
The North Face
Tok Stok
Toyota Boshoku

U
Ugg
United Pets

V
Veerah
Volkswagen
Volvo
von Holzhausen

W
Windmillkey
Womsh
Woolly Made

Y
Yuima Nakazato

Exhibit 15. Source: Brand Engagement with Next-gen Materials: 2022 Landscape by MII.

PART C
REAL TALK

MELINA BUCHER

6. COMBATING GREENWASHING WITH SOCIAL BASHING: HOW DOES THAT HELP?

2022 will probably be remembered as the year of greenwashing crackdown in the fashion industry.

This is the year when one of fashion's most adopted tools to measure the industry's environmental impact, the Higg Index, came to a halt. In June, a New York Times article[8] heavily criticized the Higg Index, claiming that the tool favors synthetic materials over natural fibers. Four days after the New York Times article was published, the Norway Consumer Authority (NCA) issued a statement[9] banning brands from using the Higg Index to make environmental marketing claims. By then, some major players—including Adidas and Kering—had already opted out of using the tool.
In July, a lawsuit was filed[10] against Swedish fast-fashion giant H&M in New York federal court,[11] accusing it of engaging in false advertising about the sustainability of its clothing. By October, French luxury group Kering, which owns brands including Gucci, Saint Laurent, Balenciaga, and Alexander McQueen, issued new guidelines for making sustainability claims. The "lesson learned" is that use of broad, generic sustainability-related statements such as "eco-friendly," "environmentally friendly," or "green" should be avoided, alongside claims of "climate neutrality".[12]

While fashion houses can pull the brakes on marketing sustainability and put in place measures to cancel words that used to attract revenue but now invite lawsuits, where does this conundrum leave:

- the material scientist deep in R&D working on the formulation of a next-gen material;
- the impact investor evaluating opportunities in funding startups that claim to be creating materials better for the environment; and
- the sustainability officer within a company stuck with having to deliver "sustainability goals" but can't seem to find that "perfectly sustainable" material that can pass scrutiny from anyone and everyone with any and every beliefs, ethics, or preferences?

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"We expect 2023 to be a transition year in which the fashion industry figures out how to share accurate information around sustainability. With increased wariness of sustainability claims and lack of comparable environmental impact data, we expect more government regulation of sustainability claims, fewer companies discussing sustainability in their products, and less consumer understanding of the impact of their choices."

Nicole Rawling
Co-founder & Chief Executive Officer, Material Innovation Initiative

What Is the Issue Anyway?

The issue for consumers is nicely summarized by Anne-Laure Descours, Chief Sourcing Officer of Puma, "This is a complex topic, but consumers want a simple answer and they also want it to be 100 percent accurate."

Vegan leather is plastic.
All plastic is bad.
Natural is better than synthetic.
Cotton is better than polyester.
Organic cotton is better than conventional cotton.

These sound bite statements assuming any environmental impact assessment is binary and/or universal, are bound to be inaccurate because the fact of the matter is never binary or universal. Unfortunately, this is the attention span of most consumers.

For those whose jobs entail making business decisions based on "sustainability claims," measuring, analyzing, and reporting based on data is essential in the decision-making processes. The Higg Index might be paused for revamp when it comes to using it to over-simplify sustainability analyses into one-word marketing tools, but for the in-house analyses, everyone is likely still going to use the Higg Index. Because for high-level sustainability and comparative analysis, it is still the best data available at a broad level to get a sense of how next-gen materials compare to incumbents. Gregory Norris, who teaches life-cycle assessment at the Harvard School of Public Health and carried out a review of the Higg Index methodology in 2016, said while many of the critics' concerns were valid, "They could have waited, but to their credit, they dug in, and they built something with today's data."[14]

For business decision-makers, this is more a data scarcity issue than a misleading marketing issue.

"Sustainability is always a series of compromises based on priorities, and we need a lot of people doing some things better, rather than a few people doing everything perfectly."[13]

Dr. Amanda Parkes, Pangaia's Chief Innovation Officer.

UNCAGED INNOVATIONS

Busting the Myths About Life Cycle Assessment (LCA)

Fashion's environmental impacts are often calculated and communicated through Life Cycle Assessments (LCAs). They typically assess the impact that goods and services have from cradle-to-gate (i.e., from raw material to when they are shipped to consumers), cradle-to-grave (i.e., from raw material to after they have fulfilled their intended use and application, and are disposed of), or more rarely, cradle-to-cradle (i.e., spanning the entire closed-loop life cycle). LCAs are critical decision-making tools in the sense that they are used to determine how "sustainable" goods and services are.

Here are a few myth-busters about LCAs when it comes to assessing the impact of next-gen materials:

ANANAS ANAM

1. DO THE "QUICK AND DIRTY" LCAS.

The crux of next-gen material impact differentiation is in the raw material elementary flows (input and output). Beyond the raw material, many next-gen materials leverage existing processing and manufacturing infrastructure. In fact, the companies set to commercialize and scale most quickly adopt existing technologies to do so. When assessing next-gen material, getting stuck on the streamlined LCA scoping (cradle-to-gate or cradle-to-cradle) requiring a comprehensive list of data is missing the primary point of differentiation.

Since next-gen material development is a reiterative process, impact assessment needs to be integrated dynamically into the R&D process based on relevant findings of hotspot analysis. What matters more is identifying the hotspots or key issues (>50% contribution of emissions/impacts) and prioritizing the allocation of resources to promote implementation in design improvements. In R&D cases where identifying hotspots using LCAs isn't consistent due to a lack of clear rules, the Product Environmental Footprint (PEF) initiative guidelines for performing hotspot analysis can be referenced.

As production moves from lab scale to pilot to commercial scale, primary inventory data is collectively accessible. LCAs can then be reiterated for varying design scenarios to check for the robustness of the hotspot analysis and avoid greenwashing product claims.

2. STOP MAKING "APPLES AND ORANGES" COMPARISONS.

LCAs are not great for comparisons between different materials. LCAs typically have high specificity levels and low levels of comparability with other materials, products, or processes. But in practice, LCAs often have been recognized and used by stakeholders to compare functionally similar competitive alternatives. Comparative LCAs are most useful to companies interested in sustainably transforming their products via technological improvements (e.g., shift to green energy grid), compositional modifications (e.g., shift from fossil-derived to plant-based material composition), and temporal and regional variations (e.g., global vs. local cultivation of raw material), as emissions reductions can be tracked reliably via product LCAs. In contrast, comparative LCAs used to make competitive marketing claims between alternatives (e.g., incumbent vs. next-gen leather) can often be subjective and disputable since the inherent uncertainty of product LCAs remain unidentified or undisclosed, increasing the possibility of greenwashing.

The parameters in an LCA that characteristically introduce uncertainty in the results include LCA methodological choices (e.g., system boundaries, allocation, etc.), assumptions (e.g., the yield of raw material), inventory data sources (i.e., primary and secondary), analytical (e.g., functional unit, inventory scale, etc.) and other significant technical factors (e.g., impact characterization factors). Since the environmental footprint for any product or process (incumbent or next-gen) depends on the technological, spatial, and temporal boundaries of the production process, comparative product LCAs using inconsistent inventory data alone are considered unreliable for comparison.

To avoid confusion and reduce apprehension about greenwashing, product-level claims and comparisons between material alternatives need to be completed following standardized guidelines that adhere to ISO regulations.

3. LCA IS NOT JUST A NUMBER.

The internal sustainability goals of a material company or brand ultimately decide how the quantitative results (scores and metrics) of the product/process LCA are interpreted and used. As mentioned earlier, sustainability goals could be product development oriented or market-based. To avoid greenwashing gaps, holistic quantitative LCAs should be encouraged instead of representing results as a single score or metric attributed to a material. Results of the product LCA evaluation should always be represented as a range of metrics to understand the trade-offs in the impacts unless a company is using a single score and metric to track its product development.

LCA also typically does not address "qualitative" elements relating to the layman's understanding of sustainability. For example, greenhouse gas (GHG) emissions remain a priority because we have the most direct knowledge and consensus of the consequences of these emissions. We also have a fairly good ability to measure GHG emissions quantitatively. The research surrounding other impacts, such as chemical waste or biodiversity, is still evolving (e.g., perfluoroalkyl substances and PFAS), both on how to measure it and what are the short- and long-term consequences. Generally, economic stakeholders need to be convinced to care about an issue, and carbon is pretty convincing.

The nice thing about LCAs, however, is they assess more than just carbon emissions. There are also assessment metrics such as land use, water use, chemical effluents, eutrophication, etc., so even if that carbon footprint number is the one that draws attention, you still have this holistic analysis of the material's production cycle (and beyond, if including end-of-life) for which to refer to as the research continues to hone in on new info (for example ecological or human health impacts).

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"Companies developing new or novel material processes/products that are environmentally preferred can use comparative LCAs as a holistic tool to track the sustainability improvements for their product. However, using material LCAs to support marketing claims and/or compare alternatives can be challenging and often disputed.

A relevant example here would be comparing the LCA of traditional wool vs. current-gen alternatives to wool (e.g., acrylic). For example, the current-gen wool process data might be detailed and updated, whereas the traditional wool inventory is considered conservative and outdated. Similarly, the system boundary assumptions (cradle-to-gate, cradle-to-grave, and cradle-to-cradle) aren't always accurately matched in most comparative studies either. In the case of traditional wool vs. synthetic wool, 'the cradle' for traditional wool production is the cultivation of grass to graze sheep, whereas, for synthetic wool or acrylic fibers, it would be the extraction of raw polymer, i.e., post-oil refinery, which means the impacts related to deposition of oil and it's extraction owing to allocation are ignored. Such varying assumptions can make comparative analysis difficult to interpret even for LCA practitioners."

Ranjani Theregowda
Environmental Data Scientist, Material Innovation Initiative

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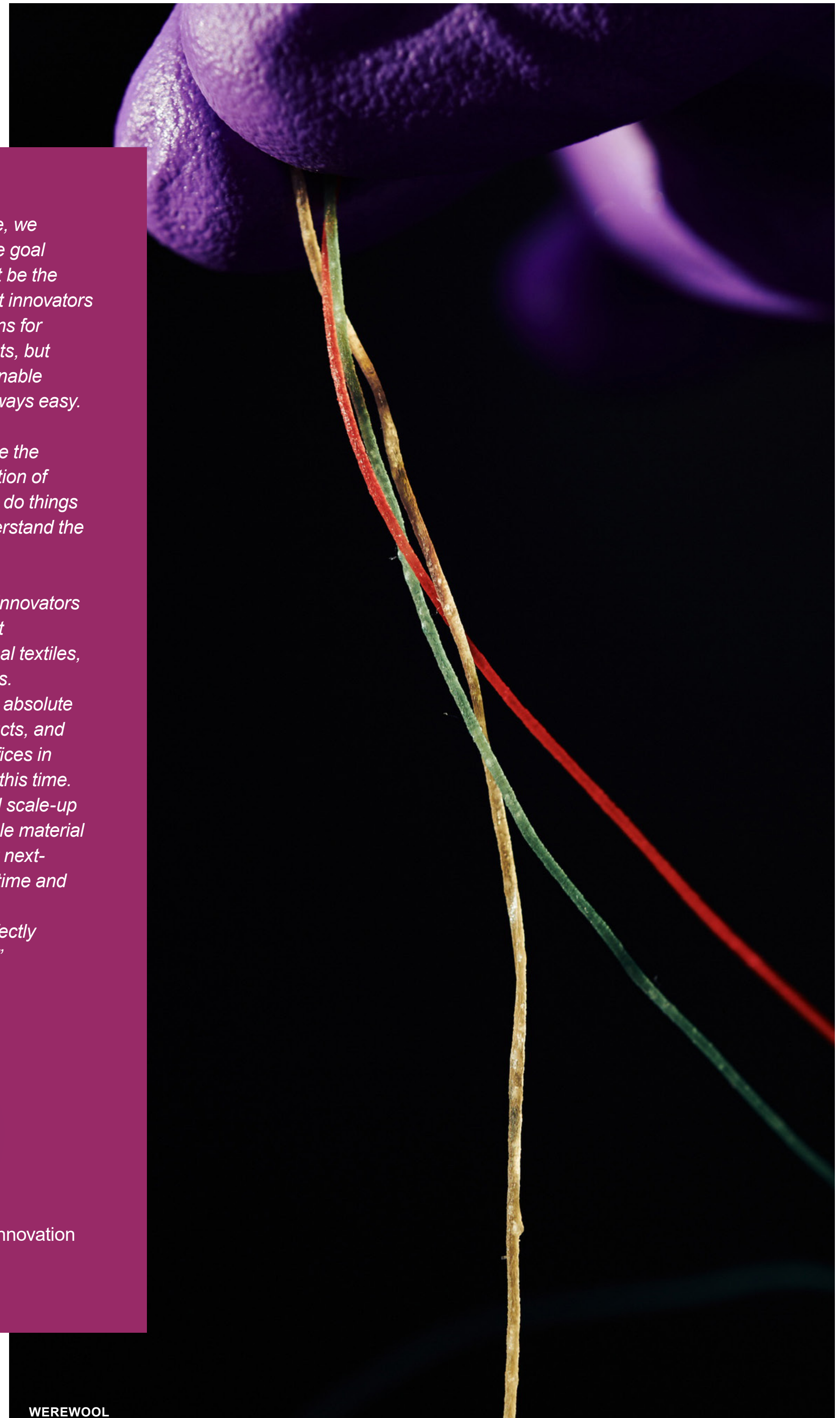
"At the Material Innovation Initiative, we believe in making progress with the goal of perfection; perfection should not be the enemy of better. We trust that most innovators will rely on the best available options for sustainable formulation components, but completely phasing out less sustainable chemistries and additives is not always easy.

Unrealistic expectations will impede the successful development and adoption of emerging solutions. To continue to do things more sustainably, we need to understand the following:

- *We should not expect next-gen innovators to single-handedly solve the vast challenges of disrupting the global textiles, chemicals, and additives markets.*
- *Performance and aesthetics are absolute requirements for next-gen products, and meeting them may require sacrifices in certain areas of sustainability at this time.*
- *The research, development, and scale-up associated with novel, sustainable material feedstocks, and chemistries that next-gen innovators can adopt takes time and investment.*
- *There is no such thing as a 'perfectly sustainable' material or product."*

Dr. Sydney Gladman
Chief Science Officer, Material Innovation Initiative



WEREWOOL

Where Do We Go from Here?

Disregarding LCAs and tools like the Higg MSI entirely because of these known flaws may not be the best option, leaving the industry with even fewer resources to make informed decisions on sustainable material selection. Instead, collaboration and targeted industry efforts can enable education and transparency on these issues, enabling us to focus on targeted solutions.

Below are just a few of the issues that require attention:
- Life Cycle Analyses (LCA)s are valuable tools for assessing impact, but data and study availability, transparency, and interpretation remain challenging.
- Choices made in the acquisition and use of raw data, including scope, boundaries, and methodologies of the LCA study, can largely influence the results of the LCA and how those results can be used to make meaningful decisions.
- Comparative analysis, or attempts to compare the impact of next-gen materials directly to the impact of incumbent materials, requires research and best practices.
- A critical mismatch exists in decision-makers' expectations compared with the realistic capabilities of budding startups concerning environmental impact evaluations.

There is an urgent need for a multi-stakeholder coalition that can develop collaborative solutions for evaluating next-gen materials' environmental impacts, help implement these solutions, and preempt incomplete, negative conclusions made by media sources.

MII'S RESPONSE:
THE ENVIRONMENTAL DATA COALITION

To address these concerns, The Material Innovation Initiative (MII) is launching an Environmental Data Coalition (EDC) to bring together key stakeholders in identifying and discussing the common issues that persist in environmental impact analysis within the next-gen materials industry. By bringing these issues to light in a collaborative format, The EDC will pinpoint the most critical areas of need for the vital role of environmental impact analysis for textiles and enable more targeted efforts to improve these issues.

Goals of the EDC:
- Create a platform for stakeholders to bring forth their concerns about data collection, measurement, analysis, reporting, and decision-making associated with the environmental impact of next-gen materials versus incumbents.
- Identify white spaces, in the form of untapped opportunities or unsolved issues within the realm of environmental impact analysis, with goals for industry-wide efforts to address these white spaces.
- Facilitate communication and collaboration to balance expectations between stakeholder groups and establish reasonable and attainable goals and procedures.
- Provide guidance and best practices for environmental impact assessment and comparative analysis to increase transparency and uniformity across stakeholders.
- Publicize advances in creating and using sustainable next-gen materials and procedures for establishing materials' environmental impact.

As a result of collaborative discussions, MII will publish a publicly available white paper detailing the critical issues at hand and, when appropriate, suggest best practices for industry stakeholders to promote more effective collaboration and consistent use of impact assessments. MII will also release publicly available educational information concerning environmental sustainability and LCAs for use by the EDC and beyond.

Upon identification of the key issues as described in the White Paper, the EDC will serve as a platform for EDC members to discuss strategies to improve and address these concerns.

BEEN LONDON BY BIOPHILICA

7. LESS STARTING UP, MORE SCALING UP

Impact requires scale. As the next-gen materials industry goes from nascent to emerging, investors and consumers are less excited hearing about the next idea of using another fruit to make leather; they are yearning for scale, go-to-market, and price parity—go big or go home.

So what's the holdup? Producing, processing, and manufacturing with next-gen materials is not only a complex process but an unfamiliar process for everyone involved in the value/supply chain. There is no single universal scale-up challenge, as the specific challenge(s) depends on the feedstock, input, production technology, processing method, and compatibility with currently existing infrastructure.

In this section, we seek to look more in-depth into a few specific scaling challenges in different types of material development, production, and manufacturing.

FORAGER

Input Case Study: Mycelium

Next-gen innovators have begun to explore the opportunities of cellular agriculture to produce sustainable alternatives to animal-derived products. Using cultivated animal cells, mycelial growth, or building blocks derived from microbes, these approaches may transform materials manufacturing. However, these budding technologies rely on new-to-the-world science and underdeveloped manufacturing at scale, with multiple pain points needing resolution. Strain engineering, optimization of media/process conditions, and converting raw outputs to finished products are each ripe for targeted innovation to mitigate risks during scale-up. Let's look at mycelium as an example.

Martin Stübler, M.Sc. M.A. is a biotech engineer who has previously worked for a Silicon Valley startup producing mycelium-based leather. Some of the challenges he had learned about scaling mycelium cultivation start from the very beginning of the growing process.

The raw material used for mushroom cultivation has to be sterilized. The sterilization process, usually conducted with an industrial autoclave, is heating the raw material to about 120 degrees Celcius for several hours, depending on the batch size. To produce about 250g of dried mycelium material, the equivalent of up to 50kg of raw material must be sterilized.[15] Given the energy required in the sterilization process (a scientific grade autoclave consumes on average about 84 kWh for 50kg of sterilized material),[17] producers are currently optimizing this process to reuse or partially sterilize the material again before usage, but there is currently no process ready to be deployed. Another issue is with the preservation of mycelium. This material is difficult as the individual hyphae have a big surface-to-volume ratio, and they tend to dry out very quickly. When the material gets too dry, it affects flexibility and durability. The current best industry practice is using humectants (similar to the food industry) to maintain a high moisture level to keep the material flexible.

All in all, cultivating mycelium and turning (as well as preserving) it into a material suitable for further manufacturing processes requires big equipment (CAPEX and space!), as well as experienced and highly skilled personnel to manage an optimum atmosphere for controlled growth.

Stübler is now the co-founder of BioFluff, producing the first-ever 100% plant-based fur. He has chosen the plant-based composite route partly for its relative ease of scaling. "At BioFluff, we are combining process steps from three independent industries that have never been combined before to create a new material that benefits from combinatorial innovation but also from additive benefits of already existing supply chains; we are standing on the shoulders of giants," said Stübler, "Fur is a challenging biomaterial to replicate, maybe that's why it's behind the curve compared to other animal replacements like leather, down and silk, but from an environmental standpoint it is one of the most impactful materials due to the low yield of fur farming, which is not a byproduct of other farming practices."

MARTIN STÜBLER / BIOFLUFF

Technology Case Study: Fermentation

Another founder who pivoted to the plant-based composite route is Bucha Bio's Zimri T. Hinshaw. In 2021, when we first met Hinshaw, he was working on creating a next-gen leather alternative using fermentation. In fact, that is where the name of his company originated, "Bucha" is from the word kombucha. By 2022, he has pivoted to working on a plant-based composite instead.

"Updating our process from growing bacterial nanocellulose in-house to purchasing from a supplier to create a composite material has been a defining decision in Bucha Bio's success. We now spend our time and energy refining and scaling our materials to meet our brand partners' needs more quickly. Brands are ready for next-gen materials now, and our top priority is to meet their order demands and build long-term, trusted relationships," said Hinshaw, "While innovation remains essential to Bucha Bio's mission—and a return to producing unique in-house components may happen in the future—we know there is a balance between creating the sustainable materials of today and investing in the innovative materials for tomorrow."

BUCHA BIO

There is a rich history in humanity's use of microbe-derived products, from beer and bread to insulin for diabetes treatment. But harnessing the power of biotechnology comes with its own scaling challenges. We see Polybion able to industrialize growing its leather alternative Celium™ by building the world's first industrial-scale facility for the production of bacterial cellulose. Polybion's new facility will allow it to reach an annual production capacity of 1.1M sq. ft. of Celium™ by the end of 2023. That's the equivalent of 275,000 luxury handbags.

But this kind of capital investment is not what most startups can afford. And venture capitalists are not exactly here to fund CAPEX needs. Seeing this gap and bottleneck in scaling up biomanufacturing, new business models like Synonym have emerged. Essentially, Synonym is a finance and development platform that connects startups with infrastructure and focuses on accelerating precision fermentation and cell cultivation production capacity.

Speaking to one of his investors, AgFunder, Synonym's founder Joshua Lachter said, "The disconnect we found is that you have to separate the developers of these products from the actual means of production. So long as the means of production are intertwined, the financial markets are going to see the means of production, the ability to get to the market, as too risky. If you're putting up the money for a specific company's $200 million fermentation facility, you have to believe that's the company that's going to be able to execute on that facility to actually build the physical infrastructure.

Most of these companies don't have the expertise—nor should they—because they're food scientists and engineers. [Investors] have to believe that they can operate the facility to its full potential and believe they can sell the full amount of this facility in the market."[18]

Lachter said further, "In much the same way that a startup internet company building its own servers is a terrible idea, it's really hard to build infrastructure. It's really hard to go through the engineering, design and permitting. All of that is exceptionally difficult and time-consuming, and at the end of it all, a single company would have with one facility there are ultimately going to be multiple, so I think it's clear that a third way is necessary, and we want to represent that third way."

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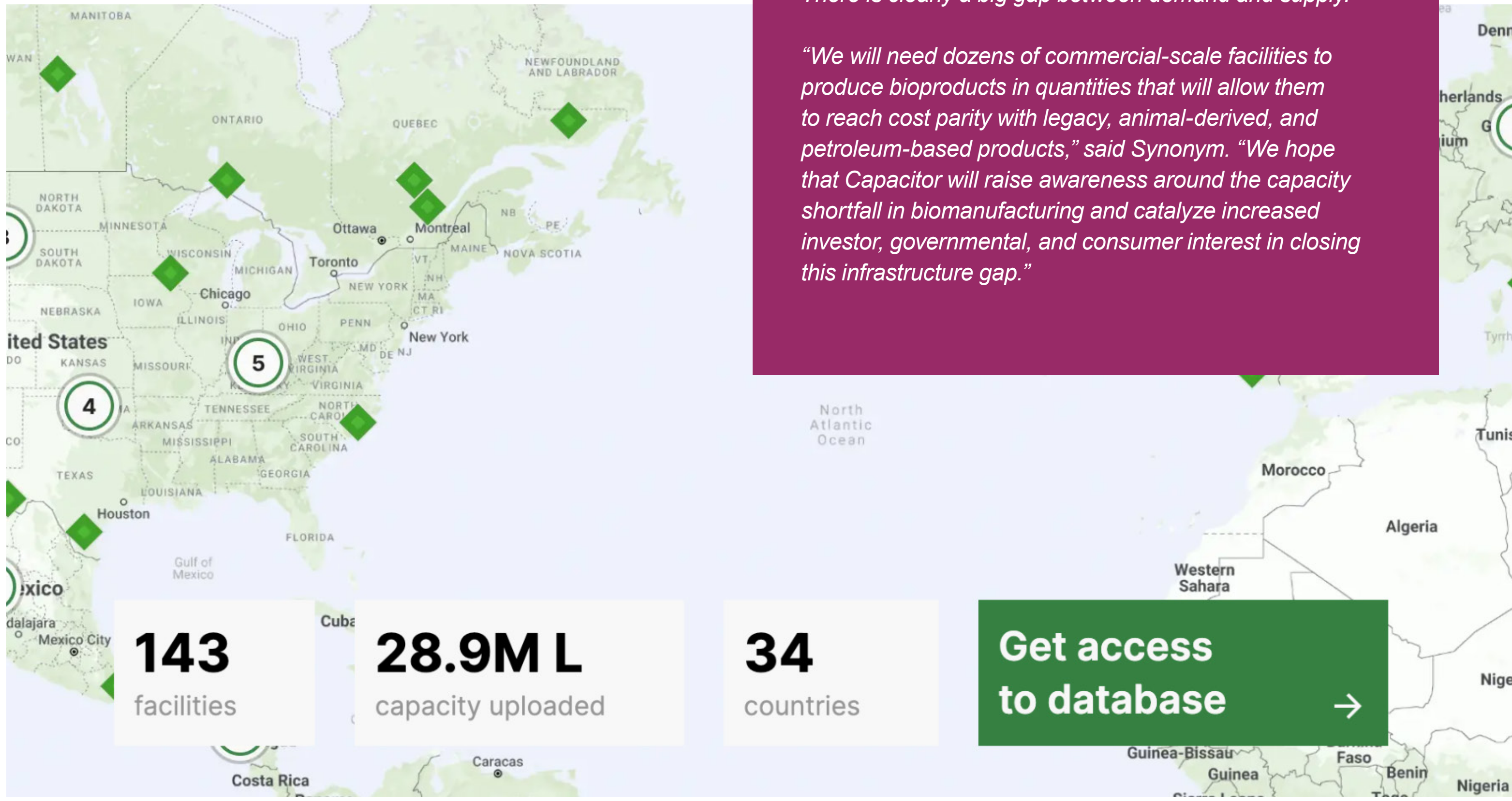
Free Database: Capacitor

Capacitor is a free database of microbial fermentation facilities worldwide that startups can use to find production space and capacity. The free resource comprehensively lists microbial fermentation facilities worldwide, helping synthetic biology companies to find capacity. Users can search using criteria such as location, scale, bioprocess, and feedstock, or view facilities on an interactive map.

Synonym partnered with the Good Food Institute, Blue Horizon, and the Material Innovation Initiative to launch this free tool for the world. It's been said for a long time that the world can potentially revolutionize the way we produce materials, energy, fuels, and food; however, we cannot currently produce it at the staggering volumes required to shift the paradigm.

This free database creates more transparency in the market, showcasing what capacity actually exists today. There is clearly a big gap between demand and supply.

"We will need dozens of commercial-scale facilities to produce bioproducts in quantities that will allow them to reach cost parity with legacy, animal-derived, and petroleum-based products," said Synonym. "We hope that Capacitor will raise awareness around the capacity shortfall in biomanufacturing and catalyze increased investor, governmental, and consumer interest in closing this infrastructure gap."



Manufacturing Case Study: Infrastructure

Now let's talk about the next stage: manufacturing with next-gen materials.

Alex Kalin, Ph.D., Senior Materials Scientist at Bucha Bio, said, "Molecules found in nature behave differently from those created in a refinery—where a traditional plastic will melt, a tree doesn't. It's a challenge to reformat plant-based materials for traditional manufacturing methods."

The global fashion industry was built on fossil fuels, which means this is what the current apparel industry's infrastructure supports. And then there are the "natural materials" from animals, traditionally requiring intense preparation and pre-processing to make them ready and suitable for manufacturing the end products. Does this necessarily mean that the shift to next-generation materials will require heavy investment by brands, asking them to leave their old, expensive infrastructure in the past? If this is the case, it is probably fair to assume that this can be a deal-breaker for many, no matter how keen they are to shift to next-gen materials.

This is the reality that all material innovators face, and it is a balancing act of creating something that is plug-and-play, or something so novel that it is not compatible with existing machinery and infrastructure and may even interact with the supply chain entirely differently. Not one way is right for all purposes, but the direction chosen will greatly impact the on-to-market timeline and scalability.

"Brands need solutions that are not only sustainable, but that also perform well, scale quickly, and are cost competitive," said Stephanie Downs, founder of next-gen leather startup UNCAGED Innovations. Coming from the plant-based food space where scaling has been a constant bottleneck for the industry, Downs knew the importance of considering compatibility with available equipment and co-manufacturers during the R&D process. She also strategically worked with technologies and inputs to make them easier and quicker to scale. "We initially looked at 3D printing of collagen-focused formulas to give us the ability to create incredible patterns and eliminate scraps, but it quickly became obvious that these solutions were unscalable and too expensive," said Downs.

After pivoting from growing bacterial nanocellulose, Bucha Bio has just set up its pilot-scale extruder, purchased from Thermo Fisher in 2022. In 2023, Bucha Bio will work with its pilot-scale machine to prepare for work with a third-party manufacturer to create continuous sheets of its material up to 45cm wide.

BioFluff, on the other hand, is leveraging existing tannery equipment to create its plant-based next-gen fur. Stübler said, "Tanneries have optimized the processing of animal fur over millennia; we are combining green plant-fiber technology with century-old tanning legacy to create a new and sustainable material. Our key to scaling success was to take our innovations from the laboratory immediately to the right contract manufacturing partners. Every biomaterial can be developed by finding the right manufacturing partners. Discovering these partners and maintaining a mutually beneficial relationship with them is key for every startup."


UNCAGED INNOVATIONS

8. STRIKING A DEAL WITH INDUSTRY GIANTS

In October 2020, Bolt Threads announced the creation of an unprecedented consortium with iconic global fashion companies—Adidas, Kering, Lululemon, and Stella McCartney. As part of this consortium, the brands commit to investing in material development with Bolt and, in return, secure exclusive access to its next-gen leather material, Mylo™. The Mylo consortium marks a major milestone in the industry as global brands come together to invest in material innovation and support material innovators in commercialization and bringing products to market.

> ***"We hope this inspires others to join forces, as a more sustainable future is something that no brand can create alone."***
>
> **James Carnes,** VP of Global Brand Strategy at Adidas

The consortium was the largest joint development agreement in consumer next-gen materials to date, marrying material science and designership, innovation, and established brand power. It stipulated that brand partners would begin bringing products featuring Mylo to market in 2021. Since then, we have seen realized deliverables, including Stella McCartney's Frayme Mylo™ bag, Lululemon's concept yoga mat and bag, and Adidas' concept Stan Smith shoes made with Mylo.

Fast forward to 2023, we have seen many more partnerships between brands and material startups popping up in the news monthly. It is now well understood that brands like Kering and BMW are a huge part of the equation to accelerate the adoption of next-gen materials in fashion, home goods, and automobiles.

But practically, how does one go about forming these partnerships? How are these collaborations different from a typical buyer-seller relationship? What should the innovators and brands expect? Everyone seems to be operating in the dark, while transparency is most needed to facilitate these deals in order to accelerate adoption of next-gen materials.

The Chicken-and-Egg Conundrum

Brands fully recognize that they are in a race to develop sustainable solutions to conventional technologies for the world's future and to remain competitive in business. However, working with material innovators and early-stage technologies is very different from the "normal course of business" that big corporations and conglomerates are used to.

Brands buy market-ready materials. But when it comes to next-gen materials, they find themselves speaking to a two-person startup team with technology, albeit promising and exciting, still in lab-scale production. Not only is the material not ready for order, but it is also more expensive than its incumbent counterpart. Most of what brands are accustomed to have yet to arrive: a fully established supply chain, availability in a wide spectrum of colors and effects, the usual size/thickness, etc., that would work with their machines.

On the other hand, it is not that material innovators do not want to be market-ready: they need brand partnerships to develop and scale materials that meet brands' performance and manufacturing requirements. Offtake agreements by brands will also significantly reduce commercial risks for material innovators. With that, it is much more feasible to fund the long development period and eventually lower the price point. However, most brands only want to invest in fully-scaled innovative materials that already meet their needs.

Brands and innovators find themselves at an impasse. Material innovators cannot give brands what they want without upfront brand support, but brands will not risk providing upfront support unless the innovators already offer what they want.
Despite the growing demand for next-gen materials, not all brands are capable or willing to provide the capital and in-house R&D capacity to support innovators as they become market-ready. Material innovators end up competing for the partnerships of a small pool of brands, while most other brands wait for materials to scale up for commercial use.[19]

Bridging the Gap

This chicken-and-the-egg conundrum may not have any obvious solutions. However, transparent communication to manage expectations effectively can go a long way.

Timeline: The development process may take years before being ready for commercialization. This timeline can be a difficult adjustment for an industry that usually sources materials within months. Brands need to understand that material innovators face the challenge of delivering materials that compare to or exceed that of their conventional counterparts while also being more sustainable. Is the material ready for prototyping? Or is the brand open to co-developing a material that will go through multiple iterations to meet its specifications and needs? Different intended applications for the brand also have huge implications on performance requirements and how rigorously the material has to be tested (e.g., a wristwatch band versus the interior of a car) and will significantly affect the realistic development and delivery timeline.

People: To buy into a new material, many parties are involved, and they must work together. Trust, patience, and empathy are key. A brand will face many bureaucratic challenges integrating a new technology outside its well-developed supply chain. New relationships and processes must be built between innovators, raw material suppliers, and manufacturers. Understanding that the brand is putting its reputation, relationships, and supply chain schedule on the line, innovators need to be transparent about what can be realistically achieved within a certain time frame and work to cooperate with all parties in the existing supply chain.

Pricing: Brands may accept to pay a premium for more sustainable materials for a while. However, brands and innovators should seek to align early on how this price tolerance may change throughout scaling the technology. These co-developments or collaborations are likely to span a relatively long time.

There are many ways to create a deal that benefits both the innovator and the brand. For example, a consortium such as Bolt's facilitates diversification and lowers the investment risks for the multiple brands involved. Some brands may be less concerned with risk diversification and prefer to invest alone in return for exclusivity.

Despite these challenges presented to both innovators and brands, what is most important is that both parties are aligned in their mission for creating a more sustainable future.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9. CONCLUSION

The emerging next-gen materials industry continues to grow. Conventional animal-derived materials, such as leather, fur, silk, wool, down, and exotic skins, are widely used in the fashion, home goods, and automobile industries. The greatest opportunities lie in developing technology and materials that inherently meet market demand for sustainability, style, and performance without the low margins, high variability, and myriad issues associated with using animals as inputs.

Of the 102 companies innovating in next-gen materials, the majority (64) work on biomimicry of animal leather. Fifteen (15) work on biomimicry of silk, ten (10) on wool, nine (9) on fur, seven (7) on down, and one (1) on exotic skins.* Over two-thirds (69) of the 102 companies are relatively young, established within the last ten years.

In 2021, we saw an unprecedented spike in capital invested in next-gen materials companies, notable exits such as Spinnova's IPO accounted partly for the sharp increase. 2022 represented a more challenging investment atmosphere, and the next-gen materials space was not immune to the adjustment. However, looking at the 10-year track from 2013 to 2022, both capital invested and number of deals continued their upward momentum.

At least US$456.75 million was raised by the next-gen material companies we track from 28 publicly disclosed deals.

More and more material manufacturers, fashion conglomerates, and automakers have added next-gen materials to their offerings and/or publicly announced to be developing next-gen materials in-house. The number of such companies has risen to 20. Notable partnerships include General Motors's investment in MycoWorks to secure joint R&D to develop a mycelium animal-leather replacement for the interiors of GM cars.

Technologies and innovation have the potential to significantly transform the industry by creating environmentally preferable and animal-free materials that meet brands' and consumers' aesthetic, performance, and price needs. As we face potentially dire climate change, we need significant investments, partnerships, and more material companies and scientists to disrupt the status quo.

Transparency, vision, and collaboration will be vital in creating a liveable future on Earth and a prosperous future for the materials industry.

**Some companies work on more than one replacement of animal-based materials. Some next-gen material companies market their material as next-gen rather than as a next-gen replacement for a specific animal material. This report places the material in a next-gen category according to its primary application in end products.*

ABOUT MII

The Material Innovation Initiative is a nonprofit think tank that accelerates the development of high-performance, animal-free, and environmentally preferred materials with a focus on replacing silk, wool, down, fur, and leather and their synthetic alternatives. We advance the next-gen materials revolution by connecting science and big ideas. We focus on research, knowledge-sharing, and fostering connections to fast-track the development of environmentally preferable and animal-free materials. We work to cultivate a global market for next-gen materials across the fashion, automotive, and home goods industries.

We work for materials that can do more while requiring less of the planet, animals, and people involved at every stage. We imagine a circular future where the default choice for your sweater, sneaker, or seat is humane and sustainable. A future where animals are allowed to live free and thrive, the planet is saved from pollution and degradation, and workers are treated fairly and with respect.

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EXHIBITS

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