MATERIAL INNOVATION INITIATIVE

STATE OF THE INDUSTRY REPORT

NEXT-GEN MATERIALS

BONUS SECTION: MARKET PROJECTION

June 2021

Cover image: PANGAIA FLWRDWN™ Fitted Short Puffer Jacket

Source: https://thepangaia.com/

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EXECUTIVE SUMMARY

(AND HOW TO USE THIS REPORT)

The Material Innovation Initiative (MII) is thrilled to offer this first-of-its-kind State of the Industry Report, and in fact, to announce the emergence of the **next-gen material industry.**

In this report, you will find research, analysis, and insights to guide your understanding of this nascent industry. Whether you are an entrepreneur or startup, investor or corporate, you can still join this space as a first mover. It's that new.

We suggest that you do not skip Part A, which includes the **Introduction.** That gives you the important context for what comes next. You don't want to miss the **founders' story (and why we can predict the future).**

In Part B, we introduce the three categories of key stakeholders in this industry, or the **3 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. Think Adidas, IKEA, and Bentley. Industry Brands can play multiple important roles in the ecosystem, including funding both 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 acceleration of commercialisation and scale-up production of next-gen materials to replace their conventional counterparts.

In each section of the 3 i's, we present data and statistics to give you an overview of the current state. We then dive into **Insider Insights** for more flavor of these industry players: What are the main risks and opportunities? Who's doing what? Who might be the winner?

Part C explores the driving forces accelerating the growth of the next-gen material industry, specifically: advancements in material science and technology, changing consumer preferences, and regulatory trends.

Because this is the first ever state of the industry report, the Material Innovation Initiative worked with our research partner SPEEDA Edge on a bonus section to address the most asked question: how big will this market be in the years to come?

The next-gen material industry is both rapidly emerging and changing. If you find something that should be in our next report, please let us know via this form.

The Material Innovation Initiative (MII) is a nonprofit 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

74
TOTAL NUMBER OF NEXT-GEN MATERIAL COMPANIES
AS OF APR 30, 2021

49 LEATHER
9 SILK
7 WOOL
6 DOWN
5 FUR
1 EXOTIC SKINS

42
NEW COMPANIES FORMED SINCE 2014

$1.29 BILLION
INVESTED
(2015 - MAY 14, 2021)

$504 MILLION
RAISED IN 2020
(NEARLY THE SAME AS THE PREVIOUS 4 YEARS COMBINED)

$293 MILLION
LARGEST FUNDING ROUND 2020

95
UNIQUE INVESTORS

$599 MILLION
TOTAL AMOUNT RAISED BY THE TOP FUNDED COMPANY

35
DEALS
(2015 - MAY 14, 2021)

41 PLANT-DERIVED
14 MICROBE-DERIVED
7 MYCELIUM
6 RECYCLED MATERIAL
4 BLENDS
3 CULTURED ANIMAL CELLS
NUMBER OF COMPANIES BY MAIN INPUT

38 OUT OF 40
LEADING FASHION BRANDS ACTIVELY SEARCHING FOR NEXT-GEN MATERIALS

Source: Material Innovation Initiative
*Note: Some companies create more than one next-gen material.
**Note: 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%).

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

CONTENTS

PART A: A NEW INDUSTRY IS BORN

1. INTRODUCTION

Have you heard of the next-gen material industry? Chances are you haven't.

This report is truly the first of its kind. The Material Innovation Initiative introduces and provides early insights into the nascent industry of next-gen materials, a term we coined based on our nomenclature assessment study,[1] to describe high performance, more sustainable alternatives to animal-derived materials (see **section 2** for full definition.)

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. That animal-based materials are simply byproducts from industrial animal agriculture that primarily supplies to the food industry, is a common misconception. Leather, for example, is the second most profitable product of a cow; and for fur, silk, and exotic skins, the animal material itself is the most profitable product.[2] 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. Given that at least two thirds of a brand's environmental footprint can be attributed to its choice in raw materials,[3] if we hope to move rapidly toward a more sustainable materials industry, we need alternatives to animal materials.

Adidas plant-based sneakers

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"The term next-gen cues innovation, and may better describe a new category of materials which has multiple characteristics (i.e., sustainable, animal-free, and high performance)."
- North Mountain Consulting Group

"Stephanie Downs, MII's other co-founder, and I have seen this sort of industry-wide change happen before, and today's materials industry looks very familiar to us."
- Nicole Rawling, co-founder and CEO of Material Innovation Initiative

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FOUNDERS' STORY (AND WHY WE CAN PREDICT THE FUTURE)

Both Nicole and Stephanie came from the world of alternative protein. Think plant-based meat like Beyond Meat and real meat grown through tissue engineering without the need to kill cows. When they started working in that industry, there were veggie burgers, but not what most people now call 'plant-based meat.' In fact, the term 'alternative protein' didn't exist when they started building that ecosystem.

The world woke up to the alternative protein industry when Beyond Meat went public in 2019, and its stock price soared 163% on the first day of trading and around 800% within a few months. But that apparent overnight success was 10 years in the making. The company was founded in 2009 with the clear vision of making meat not for vegetarians, but for mainstream consumers. **This mindset change was the tipping point that created a new industry.** Everything changed when companies began thinking about meat-eaters, analyzing what they liked about meat, and then working to replicate it. Everything shifted when companies stopped asking consumers to sacrifice, but rather used science and technology to give consumers what they wanted: the taste they were used to with the benefits of being better for the planet and animals.

Today, plant-based meat options sell out in major fast-food chains like Burger King; you can find plant-based meat right alongside beef in the grocery store; major international food companies like Nestlé and Tyson are investing in alternative proteins. Governments all over the world are working to accelerate the alternative protein industry. Today in Singapore, you can actually have a meal cooked with cultivated meat (real meat grown through tissue engineering) at a restaurant or even have it delivered to your home.

This massive growth of the alternative protein industry happened in just a few years. That is the power of creating a collaborative ecosystem, directing R&D toward the most critical areas, and shaping the public message around sustainable technology.

"People who have missed the boat are now looking for the next Beyond Meat," said Nicole, "I say look no further than the next-gen material industry. Next-gen materials are now where alternative protein was about 5 years ago."

WHERE DOES THE INDUSTRY STAND IN 2020?

Within the categories of next-gen materials, all eyes are on leather replacements. This is not surprising as leather is particularly ubiquitous across the fashion, automotive, and home goods industries, with a global value of 414 billion USD in 2017.[4]

The Covid-19 pandemic highlighted the vulnerabilities in existing industries and ignited changes across the board. In this period of crisis, some emerging industries and companies have experienced unprecedented growth. While Amazon and Zoom were among the biggest winners of 2020, for obvious reasons,[5] consumers' heightened awareness and concerns about industry practices and sustainability issues have also helped industries like alternative protein to thrive in what was otherwise a dire business environment.

When millions of mink in fur farms were culled to stop the spread of a Covid-19 variant in 2020,[6] the world saw that relying on animals for materials leaves the supply chain vulnerable in ways that next-gen materials do not. The World Health Organization and the U.S. Centers for Disease Control and Prevention stated that the majority of human pandemics start in animals and the next pandemic isn't a matter of if, but when.[7] A recent report by Boston Consulting Group predicted that peak meat consumption in North America and Europe will occur by 2025.[8] When the demand for beef drops, so will the supply of leather, and leather prices will rise. The same report also estimates that if meat consumption declines as expected, 1 gigaton of carbon dioxide equivalents will have been avoided within the next 15 years,[9] and farmland equivalent to the area of the UK will have been freed from supporting livestock.[10]

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"The most significant quantum leap advancements in technology are enabled by innovations in material science. Material technologies are among the only that can impact all fields, fulfilling basic human needs and improving the quality of life on the planet."
- Material Impact, venture capital and company builder

2020 highlighted that raising animals for their skin, fur, or feathers can be a risky business with low margins and high variability. Going forward, the greatest opportunities lie in developing technology and materials that inherently meet market demand for sustainability, style, and performance.

Consumers indicate they are ready to support this positive change. In a study of consumers in the U.S., 55% of the respondents said they would prefer a leather alternative (see **section 8** for more details).

MII has met with 40 leading fashion brands, and all but two are actively searching for next-gen materials to integrate into their supply chains.

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Fashion brands recognize the trend toward more sustainable and animal-free materials.

Just as the food industry initially struggled to achieve the taste, price, and convenience that customers desire, the current materials industry does not yet produce sustainable options at scale that meet brands' performance, aesthetic, and price requirements. But some brands are already taking an active role in promoting R&D for next-gen materials. In 2020, exciting collaborations included Lululemon, Kering, Adidas, and Stella McCartney partnering with Bolt Threads, and Ralph Lauren and Allbirds investing in Natural Fiber Welding. These major brands have the infrastructure, capital, and distribution networks that startups need to scale their ideas and bring materials to market. We anticipate more of these partnerships as the industry develops.

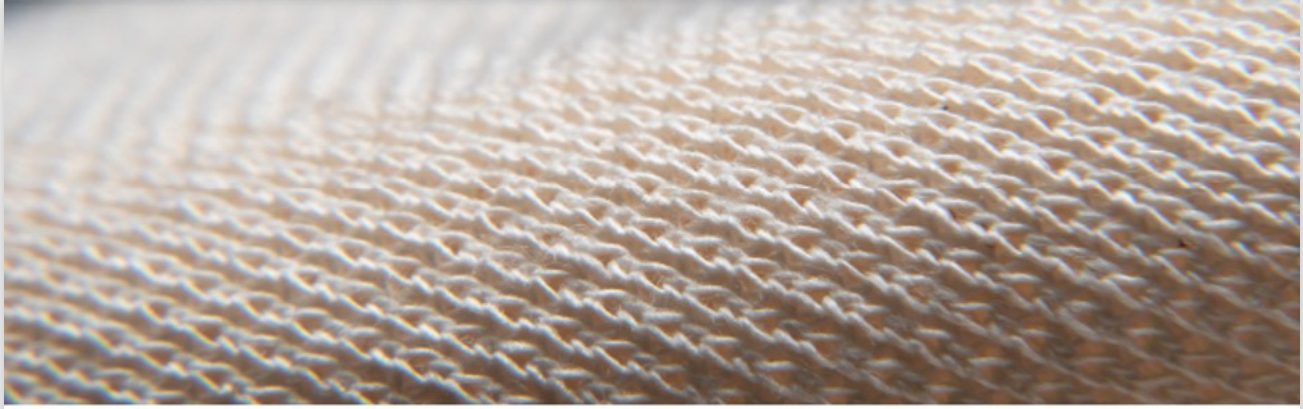
11

The New York Times

Fungus May Be Fall's Hottest Fashion Trend

A surprising group of fashion rivals including Stella McCartney and Lululemon are joining forces to back Mylo, a new mushroom leather.

Mylo, a material made from mycelium, in natural and black. Bolt Threads

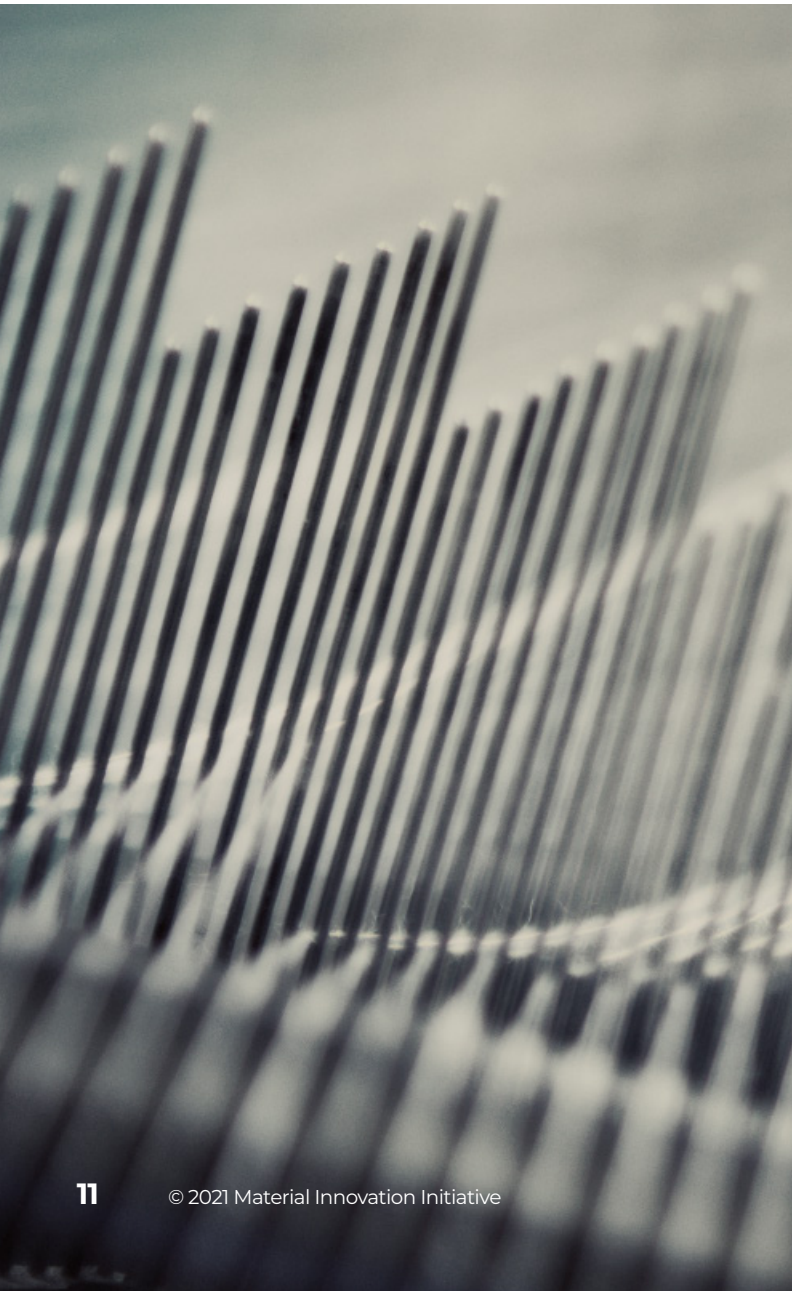


ClarusTM fabric from yarn that is 50% recycled and 50% organic virgin cotton. Photo courtesy of Natural Fiber Welding.

Ralph Lauren Corporation Announces Investment in Leading Sustainable Material Science Startup Natural Fiber Welding

Investment to help enable product development using plant-based, upcycled materials as well as create and scale a new industry standard for natural fiber recycling

12



With clear interest from consumers and brands, investors are taking notice of the opportunities for significant financial, environmental, and social return by investing in next-gen material companies. Investors see the massive potential of this space and are eager to invest in startups that can transform the materials industry. In fact, there are currently more interested investors than suitable investment opportunities.

There is significant demand for next-gen materials, but not enough supply to meet the sustainability, performance, aesthetic, scale, and price needs of brands and consumers. The Material Innovation Initiative addresses the urgent need to facilitate collaboration between industry players. including entrepreneurs, investors, scientists, material companies, and brands to increase the number of companies in this space and support the existing material companies.

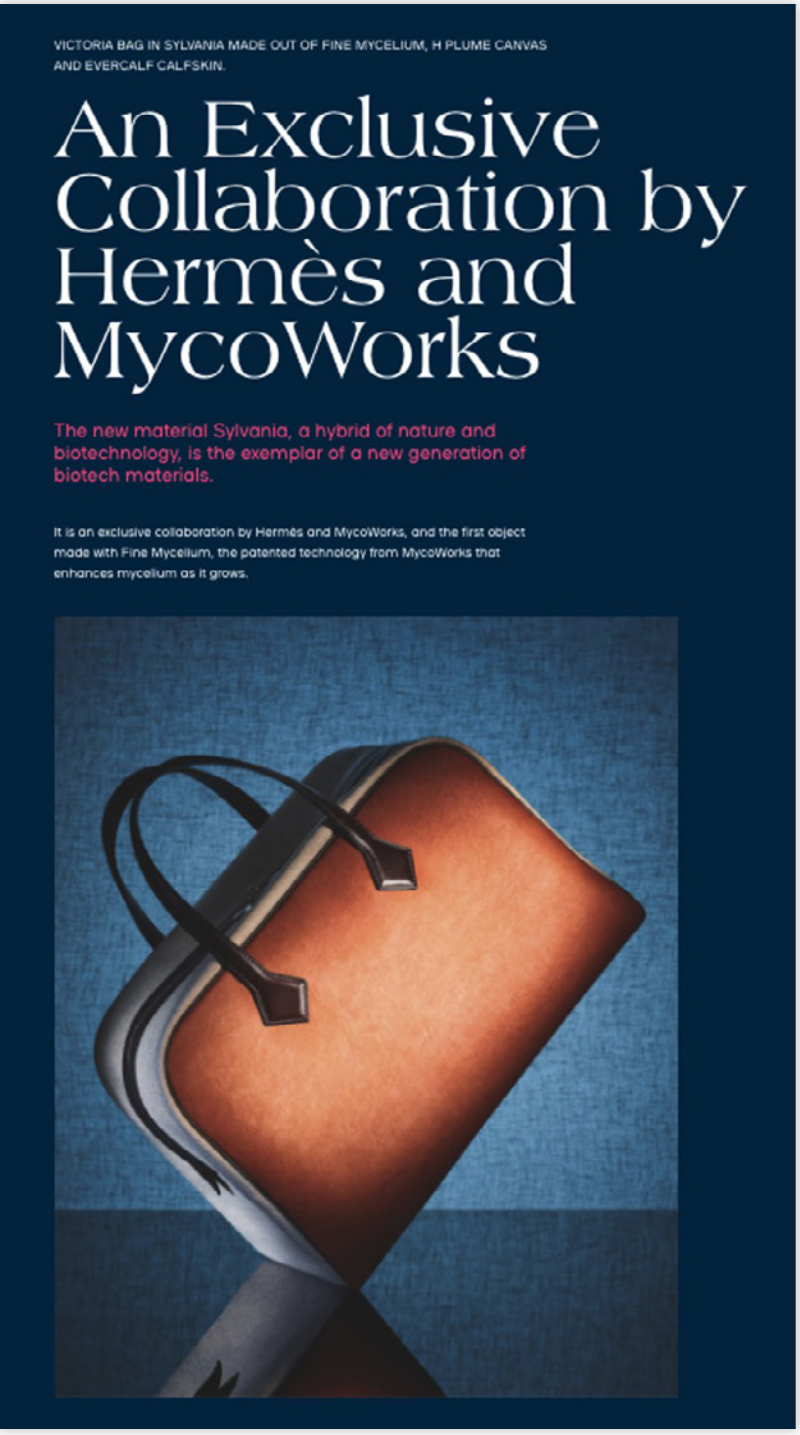
“If there’s anything I’ve learned from my time working with disruptive technologies, it’s that a rising tide lifts all boats,” said Nicole Rawling, MII’s co-founder and CEO. And in the next-gen materials industry, the tide is indeed rising.

Natural Fiber Welding Production

2021: IN THE NEWS

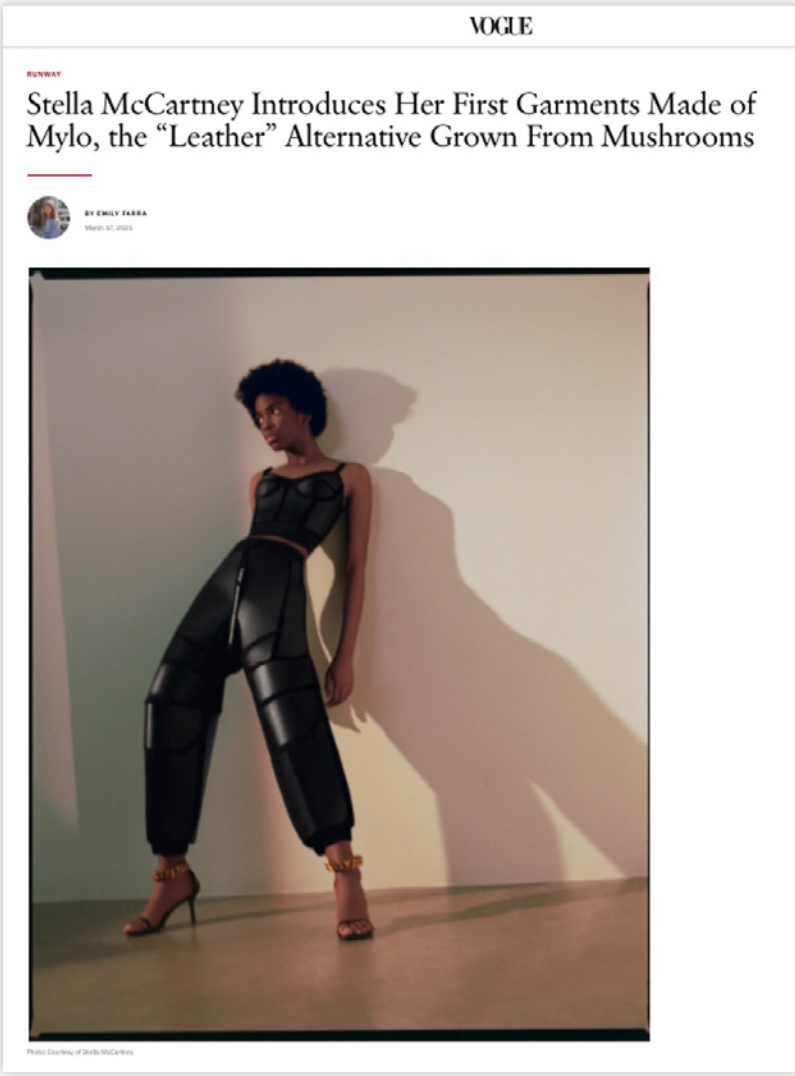
MARCH 2021

Hermès partnered with mycelium-based material startup **MycoWorks** to reimagine its classic Victoria shopper in alternative leather.[13]



MARCH 2021

Stella McCartney launched her first alternative leather garment made with Mylo by Bolt Threads.[14]



2. DEFINITION AND SCOPE

WHAT ARE "NEXT-GEN MATERIALS"?

For the purpose of this report, the term "next-gen materials" refers to materials that are livestock-free direct replacements for conventional animal-based leather, silk, down, fur, wool, and exotic skins. These replacement materials use a variety of biomimicry approaches to replicate the aesthetics and performance of their animal-based counterparts.

Examples of exclusions from this definition:

- 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;
- Dye, cut, trim, or other manufacturing and supply chain technologies.

Leather

Silk

Fur

Down

Wool

Exotic skins

DISRUPTIVE TEXTILE TECHNOLOGY

Synthetic materials are prevalent in today's world. Sustainable innovation in synthetics such as bio-based, biodegradable, or 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. Material innovations purely to replace polyester, however, are outside the scope of this report. To the extent that these broad players and technologies may become promising feedstocks or resources for next-gen material innovation, MII is creating a separate database to provide next-gen material innovators an easy way to find potential collaborators.

INNOVATORS, INVESTORS, AND INDUSTRY BRANDS

The scope, definition, limitations, and assumptions underpinning the analysis of key industry stakeholders are stated in each section in this report.

3. NEXT-GEN MATERIAL SCIENCE 101

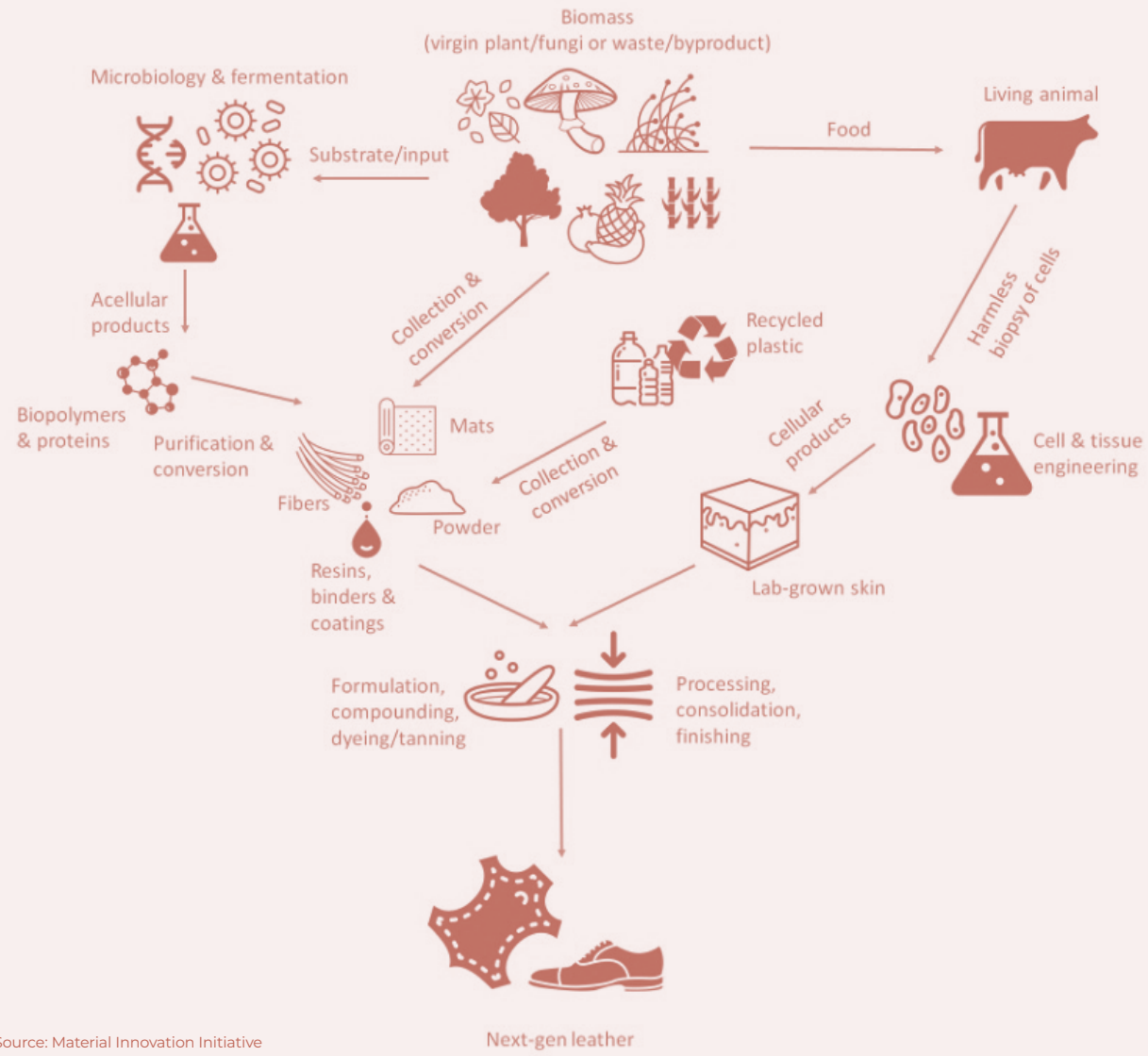
Materials science and engineering focuses on the interplay of material composition, structure, processing, and properties to achieve specific performance for a target application. In next-gen materials science, the same principles are applied to develop materials that mimic animal-derived materials or their current generation, unsustainable replacements (e.g., polyurethane leather). The science of incumbent animal-derived materials serves as a materials design guide, with the incumbents' performance as a benchmark. For example, next-gen leather materials should mimic the interconnected collagen network of leather in order to replicate its toughness and strength, while next-gen silk should mimic the silk protein and continuous fiber structure to achieve elasticity and luster. Designing next-gen materials employs biomimicry, i.e., replicating incumbent animal-derived material function, and may also employ bio-utilization, i.e., using naturally occurring materials as feedstock.[15]

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**: applies to 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 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.
- **Microbe-derived:** applies to materials that utilize cellular engineering approaches such as cell culture or fermentation processes to produce products such as proteins and biopolymers for next-gen material formulations.
- **Cultured animal cells:** applies to materials that utilize tissue engineering approaches to grow animal cell constructs in the laboratory.
- **Recycled material:** applies to materials that utilize recycled plastic or textile feedstock as a main input.
- **Blend:** applies to materials that use a blend of components not well-captured by any of the above categories.

LUXTRA clutch purse made with Fruitleather Rotterdam leather

Figure 3.1 Conceptual landscape of next-gen leather materials



Source: Material Innovation Initiative

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"The transformation of orange peel and algae into fabric and grape residue into plant-based leather are just a few of the great ideas that have been realized. I'm convinced that technical innovations will be the solution to many of the environmental challenges the textile industry is facing and will contribute to a more sustainable consumption."
- Karl-Johan Persson, H&M Group

Using Figure 3.1 above as a reference, there are a variety of approaches for producing a next-gen material such as leather.

The most popular approach involves the use of plants (and/or fungi, algae) as feedstock for next-gen materials. Virgin plant matter or the byproduct/waste of plant agriculture provides a rich, regenerative set of resources from which to build a functional material formulation. The plant matter may be harvested and incorporated with minimal chemical alteration, such as powdered apple peels (e.g., Beyond Leather), pineapple leaf fibers (e.g., Piñatex), or Kapok fiber (e.g., Flocus). In other cases, the plant matter is chemically/biologically modified, or manipulated to a new form, such as with cellulosic fibers from dissolved and regenerated orange juice waste (e.g., Orange Fiber), the welding of natural fibers (e.g., Natural Fiber Welding), and polymer resins derived from plant oils (e.g., the bio-based PU or rubber of several next-gen leather formulations).

DeLaunay jacket made with Piñatex® by Ananas Anam

Due to the unique nature of the branched, fibrous structure of the chitin-rich material, mycelium has found specific use as an alternative to leather. The mycelium is grown in indoor farms on feedstock such as plant waste and then processed into leather-like sheets. With over seven innovators employing this fungi-derived material in their formulations, mycelium deserves its own category within the ecosystem of next-gen leather materials.

The cultured animal cell or tissue engineering approach takes a one-time harmless biopsy from animals and grows these cells on scaffolds in the laboratory into tissues such as skin. This approach is distinctive from the other process flows in that the semi-finished product is expected to be identical to the incumbent material - for next-gen leather, a sheet of animal hide (skin). Currently, the tissue engineering approach has only been attempted with next-gen leather (e.g., VitroLabs), but theoretically, exotic skins could be produced with the same technology. With further advancement in follicle tissue engineering, next-gen fur, wool, or down could also be feasible, where cell-based constructs allow hair or feathers to be lab grown.

Another formulation pathway Involves cell culture in the laboratory, but instead of using cells to grow tissues, cells are used as factories for producing specific compounds. These cells can be from a variety of sources (e.g., animal, plant, bacteria, yeast) and are placed in bioreactor chambers, often with plant-based feedstock, with an optimized environment for production of the target compound. In one example, the cells may produce native molecules, like bacteria generating cellulose or mammalian cells generating collagen. In other techniques such as precision fermentation, the cells, typically microbes such as yeast or bacteria, are genetically engineered to produce foreign molecules, such as recombinant proteins, biopolymers, or chemical precursors. In either approach, the molecules are harvested from the cell culture and converted into components such as fibers and resins which can then be used in the next-gen material composition. The majority of next-gen innovation employing these cellular engineering approaches is in leather, with bacterial cellulose (e.g., Malai) or recombinant collagen (e.g., Provenance Bio) serving as the key target

components, and in silk, with spider silk protein as the target output (e.g., AMSilk). However, these microbial factories are also capable of producing proteins such as keratin, which forms the hair structure of fur, wool, and cashmere, as well as sustainable biopolymers that replace synthetic polymer components (e.g., polyester, polyurethane) for next-gen materials.

Both the cultured animal cells approach and the microbe-derived approach are forms of cellular agriculture. The former produces cellular products, where the output consists of the cells in the form of tissue constructs, while the latter produces acellular products, i.e., the target molecules absent the cells themselves.

In addition to the biologically derived materials listed above, recycled materials can also be employed as sustainable components in next-gen materials. Plastic water bottles or textiles can be collected and reprocessed into a variety of forms, such as nonwoven fibers in next-gen down (e.g., Save The Duck) or yarns for next-gen wool (e.g., OSOMbrand). Although these materials still originate from fossil fuels, their reuse in a recycled format improves the circularity of the material inputs and provides a new life for plastic waste, avoiding the use of virgin petrochemicals.

Blends are those materials without a single component comprising more than 50% of the input or those with no component over 50% that can be attributed to one of the above categories.

In all main input categories listed above, petrochemical derivatives may be present in the form of binders, coatings, or fibers. While MII practices “progress over perfection” as a means to innovation, the next-gen ecosystem is tasked with an enormous white space opportunity to completely eliminate the use of petrochemicals in their material formulations.

Hugo Boss shoes made with Piñatex® by Ananas Anam

PART B:
KEY STAKEHOLDERS OR "THE THREE I'S"

4. INNOVATORS

OVERVIEW

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

The lists focus on material innovators and are not exhaustive. Not included are business-to-customer companies that do not develop and create their own 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.

Of the 74 companies, the clear majority (49) focuses on biomimicry of animal leather. Nine (9) focus on biomimicry of silk, seven (7) on wool, five (5) on fur, six (6) on down, and one (1) on exotic skins.*

These companies employ a variety of input 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. In the cases where a company has plans to develop more than one type of next-gen material, the company will only be listed if that product is at least in R&D.

The next-gen materials industry and the innovative companies within this ecosystem develop at a fast pace, as can be seen in Figure 4.3 showing the year-on-year number of new companies formed. All company references are purely illustrative. Please check our website (https://www.materialinnovation.org/) for the latest company information.

*Some companies work on more than one replacement of animal-based materials.

Table 4.1 Next-gen material companies (in alphabetical order)

Company name	Material name (if different from company name)	HQ	Founders	Year founded	Biomimicry	Main Input
Amadou Leather	-	GBR	Irene Marie Seelig	2016	Leather	Plant-derived
AMSilk	Biosteel® (fibers & finishing)	DEU	Thomas Scheibel	2008	Silk	Microbe-derived
Ananas Anam	Piñatex®	GBR	Dr. Carmen Hijosa	2011	Leather	Plant-derived
Articor Cork Products	-	ESP	Unavailable	1986	Leather	Plant-derived
Barktex	-	DEU	Mary Barongo, Oliver Heintz	1999	Leather	Plant-derived
Beyond Leather	Leap™	DNK	Hannah Michaud, Mikael Eydt	2016	Leather	Plant-derived

Company name	Material name (if different from company name)	HQ	Founders	Year founded	Biomimicry	Main Input
Bio2Materials	-	POL	Katarzyna Szpicmacher, Aleksandra Kantor, Prof. Artur Bartkowiak	2018	Leather	Plant-derived
Biophilica	Treekind™	GBR	Mira Nameth	2019	Leather	Plant-derived
Biotecam	Texticel	BRA	Ricardo Remer, Wim Degrave	2012	Leather	Microbe-derived
Bolt Threads	Mylo™, Microsilk™	USA	Dan Widmaier, David Breslauer, Ethan Mirsky	2009	Leather, Silk	Mycelium, Microbe-derived
Bucha Bio	Bucha Leather	USA	Zimri T. Hinshaw	2019	Leather	Microbe-derived
C-Combinator	-	PRI	Geoff Chapin	2020	Leather	Plant-derived
Coronet Spa	Coronet BioVeg, Coronet Maison, Coronet Innovaction	ITA	Enrico De Marco	1966	Leather	Blend
Culthread	-	GBR	Rina Einy	2018	Fur	Recycled material
Desserto	-	MEX	Adrián López Velarde, Marte Cázarez	2019	Leather	Plant-derived
Devo Home	-	UKR	Oksana Devoe	2008	Fur	Plant-derived
Ecopel	KOBA® Faux fur	CHN	Christopher Sarfati	2003	Fur	Blend
EcoSimple	-	BRA	Cláudio Rocha, Marisa Ferragutt	2010	Wool	Recycled material
EcoSupreme	-	USA	Ivan Wang	2008	Down	Plant-derived
Ecovative Design	MycoFlex™, Forager™ Hides	USA	Gavin McIntyre, Eben Bayer	2007	Leather	Mycelium
ENKA	-	DEU	Parent Company: International Chemical Investors Group	1924	Silk	Plant-derived
Faborg	Weganool™	IND	Shankar Dhakshinamoorthy	2015	Wool	Plant-derived
Faircraft	-	FRA	Haïkel Balti, Cesar Valencia-Gallardo	2021	Leather	Cultured 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
Frumat	AppleSkin™	ITA	Hannes Parth	2008	Leather	Plant-derived
Grado Zero	Muskin, BioGreen Padding	ITA	Giada Dammacco, Filippo Pagliai	2001	Leather, Down	Plant-derived
Gunas New York	Mulbtex™	USA	Sugandh G. Agrawal	2009	Leather	Plant-derived
House of Fluff	BIOFUR™	USA	Kym Canter	2017	Fur	Blend

Company name	Material name (if different from company name)	HQ	Founders	Year founded	Biomimicry	Main Input
Ipeker	-	TUR	Gaffarzade Mehmet Efendi	1930	Silk	Plant-derived
Karu	Tilex	ARG	Verónica Bergottini	2019	Leather	Microbe-derived
KD New York	Vegetable Cashmere™	USA	David Lee, Tricia Kaye	1980	Wool	Plant-derived
Le Qara	-	PER	Jacqueline L. Cruz, Isemar Cruz	2017	Leather	Microbe-derived
Lignopure	Lignoleather	DEU	Joana Gil Chavez, Wienke Reynolds, Stefan Boersting	2019	Leather	Plant-derived
MakeGrowLab	Transleather	POL	Roza Janusz, Josh Brito	2016	Leather	Microbe-derived
Malai	-	IND	Zuzana Gombošová, Susmith C S	2018	Leather	Microbe-derived
Modern Meadow	Zoa™	USA	Andras Forgacs, Gabor Forgacs, Karoly Jakab, Francoise Marga	2011	Leather	Microbe-derived
Mogu	-	ITA	Maurizio Montalti, Stefano Babbini, Federico Maria Grati	2015	Leather	Mycelium
MYCL (Mycotech Lab)	Mylea™	IDN	Annisa Wibi, Adi Reza Nugroho, Ronaldiaz Hartantyo, Arekha Bentangan, Robby Zidna Ilman	2015	Leather	Mycelium
MycoWorks	Reishi™	USA	Philip Ross, Sophia Wang, Eddie Pavlu	2013	Leather	Mycelium
Mylium	-	NLD	Iris Houthoff	2018	Leather	Mycelium
Natural Fiber Welding	Mirum®	USA	Luke Haverhals	2015	Leather	Plant-derived
Neffa	MycoTEX®	NLD	Aniela Hoitink	2016	Leather	Mycelium
Newlight	AirCarbon™	USA	Kenton Kimmel, Mark Herrema	2003	Leather	Microbe-derived
Nova Kaeru	beLEAF™	BRA	Eduardo Filgueiras	2006	Leather	Plant-derived
Nuvi Nomad	Teak Leaf Leather	THA	Nina Rössler	2014	Leather	Plant-derived
Oleago	Oleatex™	TUR	Eşref Açık, Recep Eroğlu, Emre Eroğlu	2021	Leather	Plant-derived
Ono Collaborations	Cork Tencel Fabric	CHE	Bernadette Christina Bodenmueller	2017	Leather	Plant-derived
Orange Fiber	-	ITA	Enrica Arena, Adriana Santanocito	2014	Silk	Plant-derived
OSOMbrand	OSOMtex®	USA	Patricia Ermecheo	2016	Wool	Recycled material
Panama Trimmings	Viridis®	ITA	Giuliano Pinato	1981	Leather	Plant-derived

Company name	Material name (if different from company name)	HQ	Founders	Year founded	Biomimicry	Main Input
Pangaia	FLWRDWN™	GBR	Miroslava Duma, Jasmine Mullers, Rachna Bhasin, Nathalie Longuet	2018	Down	Plant-derived
Phool.co	Fleather	IND	Ankit Agarwal	2017	Leather	Microbe-derived
Pretty Simple	-	VNM	Suong Hoang	2016	Leather	Plant-derived
Primaloft	-	USA	Unavailable	1983	Down	Recycled material
Provenance Biofabrics	-	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	2015	Leather	Cultured animal cells
Save The Duck	Plumtech®	ITA	Nicolas Bargi	2012	Down	Recycled material
Seevix Material Sciences	SVX™ Spidersilk	ISR	Shlomzion Shen, Shmulik Ittah	2014	Silk	Microbe-derived
Seringueira	-	BRA	Wilson Antônio Manzoni	2016	Leather	Plant-derived
SmartFiber AG	SeaCell™	GBR	Subsidiary of Lenzing AG	2005	Silk	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	2014	Wool	Plant-derived
Studio Tjeerd Veenhoven	Palmleather	NLD	Tjeerd Veenhoven	2000	Leather	Plant-derived
Tenbro	-	CHN	Unavailable	2002	Wool	Plant-derived
Ultrafabrics	Ultraleather® Volar Bio	USA	Clay Andrew Rosenberg, Barbara Danielle Boecker-Primack	1966	Leather	Blend
Unreal Fur	-	AUS		2011	Fur	Recycled material
Vegea	-	ITA	Francesco Merlino, Valentina Longobardo	2016	Leather	Plant-derived
VitroLabs	-	GBR	Ingvar Helgason	2016	Leather, Exotic Skins	Cultured animal cells
Von Holzhausen	Technik Leather, Banbū Leather	USA	Vicki von Holzhausen	2015	Leather	Plant-derived

Have we missed anything? Please let us know through this form.

Table 4.2 Material manufacturers that have next-gen materials in their offerings

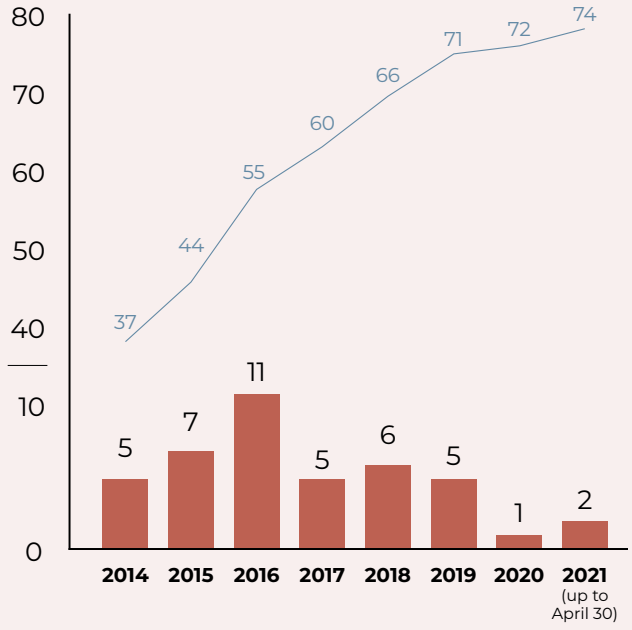
Company Name	Material Name	Headquarters	Biomimicry	Main Input
3M	Thinsulate™ Insulation - Featherless	USA	Down	Recycled material
Fiscatech	E-ULTRA®	ITA	Leather	Plant-derived
General Silicones	Compo-SiL®	TWN	Leather	Blend
ISA TanTec	COSM™ HyphaLite, COSM™ VeraLite	MAC	Leather	Plant-derived
Jord	Suberhide™	USA	Leather	Plant-derived
Lenzing	Tencel™	AUT	Silk	Plant-derived
Thermore	Ecodown®	NLD	Down	Recycled material
Toray Industries	Ultrasuede®	JPN	Leather	Blend

TREND

Of the 74 companies innovating in next-gen materials, 42 were established since 2014. Most (30) of these 42 new companies focus on leather biomimicry. In the same period, three (3) companies were formed that focus on biomimicry of silk, four (4) on wool, two (2) on fur, two (2) down, and one (1) on both leather and exotic skins.

In 2016 alone, 10 new companies were formed to create next-gen leather. Plants or plant-derived materials have historically been the main input for leather alternatives, but recently more new companies are using mycelium and microbe-derived materials to create their next-gen leather.

Figure 4.3 Number of companies growth trend



Year	Leather	Silk	Wool	Fur	Down	Exotic Skins
2014	1	2	1	-	1	
2015	5	1	1	-	-	
2016	10	-	1	-	-	1*
2017	4	-	-	1	-	
2018	3	-	1	1	1	
2019	5	-	-	-	-	-
2020	1	-	-	-	-	-
2021 (up to April 30)	2	-	-	-	-	-

*VitroLabs creates both leather and exotic skins and is thus counted as "1" under leather and "1" under exotic skin, but is NOT counted twice under "Number of companies formed" and "Total number of companies."

INSIDER INSIGHTS

In 2020, successful collaborations between next-gen material companies and industry brands (see **section 1 Introduction**) have made headlines in fashion news. Although next-gen materials are commonly associated with leather made from plants, for example: pineapple (Piñatex® by Ananas Anam), cactus (by Desserto), grape (by Vegea), mango (by Fruitleather Rotterdam), and apple (by Frumat), many different technologies and inputs are part of reimagining next-gen materials. The following aims to shed light on the spectrum of offerings across different material categories by companies around the world.

Spiber

IN

Spiber Inc. is a Japanese biotechnology company developing synthetic spider silk without the use of animals or petroleum resources.

Tech: Brewed Protein™ is the company's sustainable material inspired by spider silk and produced via its proprietary fermentation process. First, the code for the desired protein is inserted into microorganisms. Using the necessary sugars and minerals, these microorganisms grow the desired protein in a bioreactor. After fermentation is complete, the protein is purified and dried into a pellet or powder. Brewed Protein can then be processed into a variety of materials, e.g. fibers with a silky sheen, spun into yarns with cashmere- or wool-like properties.

Scale: The company is currently constructing the world's largest structural protein fermentation facility in Thailand. With this expansion, Spiber aims to manufacture sustainable protein-based materials at a competitive cost. Commercial production of Brewed Protein polymer is expected to begin in the later half of 2021, with a production capacity of several hundred tons per year.

"Spiber is essentially growing protein (polymers), which can potentially be used in a very wide variety of applications. Using precision fermentation, Spiber has the ability to create bespoke proteins that may enable suites of next-gen materials to outperform current natural and synthetic fibers. Spiber has told us that while they are now focusing on silk and cashmere-like materials, because of the versatility of Brewed Protein™, they are also exploring other applications such as next-gen leather and fur alternatives. Importantly, Spiber has overcome the industry-wide challenge to process their raw protein into a robust fiber that can then be spun into yarn (wool-like, cashmere-like) or filament (silk-like) and woven or knitted into fabric, or processed into other forms, such as non-woven, fur-like, hair-like materials."

- Dr. Sydney Gladman, Chief Science Officer of MII

PANGAIA

IN

PANGAIA is a UK materials science and lifestyle products company. The company aims to solve environmental problems through the development of sustainable materials, treatments, and dyes in partnerships with researchers in Europe, Japan, Korea, and the United States. One of its material creations is FLWRDWN™, a plant-based and petroleum-free alternative to duck and goose down.

Tech: Using PANGAIA's proprietary technology, FLWRDWN™ is a biopolymer created from flowers and infused with a cellulose-based aerogel for increased durability, thermal insulation, and water resistance. It is the first time that this kind of flower has been used in a loose-fill insulation. The material is fully biodegradable, hypoallergenic, and animal-free. FLWRDWN™ has been in development by the PANGAIA's Italian scientists for over 10 years and the patent covers the production method of the flower, biopolymer, and aerogel to create FLWRDWN™.

Scale: The company's brand strategy is not limited to apparel and PANGAIA is currently exploring innovations in the skincare and food space. The goal of the brand is to improve access to sustainable materials and drive their adoption on a global scale. To achieve this, B2B is crucial and will take different forms at PANGAIA, including sharing its innovations at material stage, and through white label manufacturing and corporate gifting programs.

"What I found most interesting is Pangaia's business model. From the outside, Pangaia looks like a direct-to-consumer company that has built a successful brand in a short period of time. But Pangaia plays multiple roles in the supply chain: in addition to selling its own design as a fashion and apparel brand (D2C), it's also a material innovator that creates materials like FLWRDWN™ and supplies them to other brands (B2B). And Pangaia is a buyer as well, sourcing from other material innovators to create its design (its grape leather sneakers are one example.) The company told us that its growth mainly happened during 2020, and that it now has a 125-member team. It's even more exciting to learn that Pangaia has plans to expand into other verticals like food and skincare. The multifaceted positioning of Pangaia may prove to be a competitive edge."

- Elaine Siu, Chief Innovation Officer of MII

NATURAL FIBER WELDING, INC.

IN

Natural Fiber Welding, Inc. (NFW) is a material technology platform company bringing to market new manufacturing routes and material chemistry that alter how plant-based materials perform in products. One of its material creations is MIRUM®, a plant-based leather that uses no petroleum-based plastics like polyurethane or PVC.

Tech: The chief technology of the platform is based on a patented plant-based curative and process to cure natural rubber and create high performance, all-natural leather like materials. This enables the creation of all natural composites that use a diverse set of natural fillers and fibers (cork shavings, rice hulls, and coconut fibers, among others) that deliver the performance, sustainability, and aesthetic needs for fashion, footwear, upholstery, and automotive industries. The platform delivers tunable final performance properties (rigidity, suppleness, elasticity, tensile strength, etc.) based on the raw material components as well as variations in the manufacturing process conditions. The resulting material can deliver a broad set of grains and finishes, from leather like to geometric or nature-inspired looks and feel.

Scale: In February 2021, NFW announced plans to open a new 110,000-square-foot manufacturing space for production of MIRUM®. This expansion will more than double the company's existing manufacturing capacity. The company plans to eventually produce tens of millions of square feet of MIRUM® per year for global brand partners.

"Their products seem significantly customizable. We examined their entire swatch book, which contains a variety of colors, thicknesses, finishes, and backings. In talking with NFW, what stood out to me was that their technology platforms can produce not only flat leather-like materials, but also cured rubber that can be formed and shaped in multiple dimensions. This means that NFW could produce all of the components of a shoe from its materials, which are all bio-based with zero plastics. This is extremely desirable from a life-cycle and end-of-life perspective, enabling true circularity and new ways to think about recycling products."

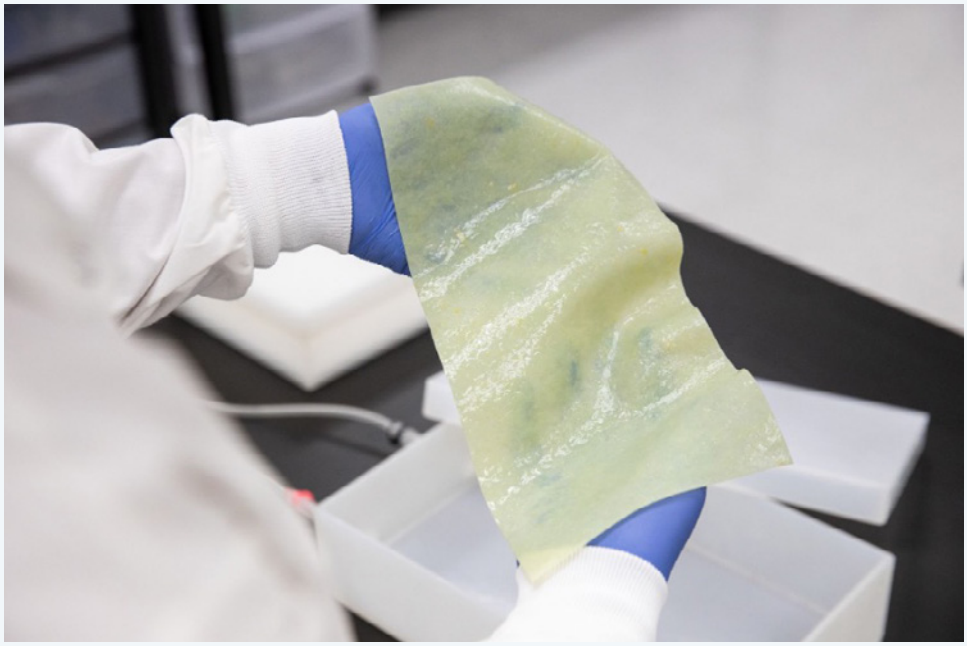
- Thomasine Dolan, Fashion Design Specialist of MII

VitroLabs Inc

IN

VitroLabs is a tissue-engineering platform company growing calf hides from animal cells, eliminating any need to raise or slaughter animals.

Tech: VitroLabs is producing real calf leather through tissue engineering, also known as cultivated leather. The cultivation process starts with a one-time small sample of cells from an animal. The cells are then placed within a proprietary bioreactor. The bioreactor facilitates the natural growth process by providing a nutrient-rich environment in which the cells can grow. Within this environment, the cells make collagen and other key proteins that make up the cow hide. Cultivated hides have the same cellular composition of traditional hides used in traditional leather. VitroLabs hides can be grown in just a few weeks, instead of the 2-3 years it takes to rear an animal, and can be tanned with significantly fewer chemicals and a reduced tanning process. Cultivating animal hides to make real leather provides the positive qualities: look, smell, durability, etc. of traditional cow leather, without the negative impact on animal welfare and the environment.



Scale: Moving from R&D to pilot scale.

"No matter how advanced biomimicry techniques may become, some people will continue to only want the 'real thing.' This is the case for meat, and it will be for leather. Therefore, at least part of the solution to the dilemma of balancing consumer demand and harm to the environment and animals ought to be to revolutionize the production method. There is nothing inherently wrong with the end product, be it meat or leather. We need to fix how they are produced. Why are we raising a live animal as the production unit of the end product, creating all the negative impact to environment and welfare, as well as depleting natural resources, when the production unit can be a bioreactor instead?

Cultivated meat research is taking place in hundreds of companies and academic laboratories around the world, in order to create meat products at industrial scale. We are already seeing the early signs of this in the materials space. I've seen first hand how quickly change can happen. Promoting cultivated meat research to the Singapore government agencies as a novel food production method, announcing the world's first regulatory approval for cultivated meat sale, and then the general public being able to eat cultivated meat in a restaurant - all of this happened within 3 years. That gives me confidence we will also see tissue engineering revolutionize the material space."

- Elaine Siu, Chief Innovation Officer of MII

5. INVESTORS

OVERVIEW

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

The data collected and analyses conducted are based solely on MII's list of companies in table 4.1. The list of investors, investment figures, and other data are severely limited by publicly disclosed information. Academic funding, 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 to each individual company or investor, are therefore likely underestimated.

Beyond the information in this section, many investors are evaluating deals, but have not yet completed their first investment in this space. MII expects the list of investors to look very different in our next State of the Industry Report. All investment, investor, and company references are purely illustrative.

Silk Dress by Bolt Threads for Stella McCartney

IN

Investors on the panel at the Rethinking Materials 2021 conference were asked whether 2021 will be a down year, average year, or an exceptional year for innovation and deal making in sustainable materials.

On a scale of 1-10, with 10 being most exceptional, all panelists unanimously said it will be an 11.

Table 5.1 Investors in next-gen material companies by deal count

The following is a list of investors in the next-gen material companies listed in table 4.1, in descending order by number of investments. Only publicly disclosed information is included.

Investor	Number of Investments	Number of Companies Invested In	Companies	Investor Type	Headquarters
Horizons Ventures	4	1	Modern Meadow	Venture Capital	Hong Kong
SOSV	4	2	Bucha Bio, MycoWorks	Accelerator, Micro VC, Venture Capital	New Jersey, USA
Formation 8	3	1	Bolt Threads	Venture Capital	California, USA
Foundation Capital	3	1	Bolt Threads	Venture Capital	California, USA
IndieBio	3	1	MycoWorks	Accelerator	California, USA
MUFG Bank	3	1	Spiber	Investment Bank, Venture Capital	Tokyo, Japan
Novo Holdings	3	2	AMSilk, MycoWorks	Venture Capital	Hellerup, Denmark
Rockstart	3	1	Beyond Leather	Accelerator, Venture Capital	Noord-Holland, The Netherlands
8VC	2	1	MycoWorks	Venture Capital	California, USA
AgFunder	2	1	Modern Meadow	Venture Capital	California, USA
Alafi Capital	2	1	Bolt Threads	Venture Capital	California, USA
Archer Daniels Midland Company (ADM)	2	1	Spiber	Corporation	Illinois, USA
Artis Ventures (AV)	2	1	Modern Meadow	Venture Capital	California, USA
Collaborative Fund	2	1	Modern Meadow	Micro VC	New York, USA
DCVC Bio	2	1	MycoWorks	Venture Capital	California, USA
East West Capital Limited	2	1	Bolt Threads	Venture Capital	Sydney, Australia
Founders Fund	2	1	Bolt Threads	Venture Capital	California, USA
ICONIQ Capital	2	1	Modern Meadow	Family Investment Office, Private Equity Firm, Venture Capital	California, USA
Mission Bay Capital	2	1	Bolt Threads	Venture Capital	California, USA
Ralph Lauren Corporation	2	1	Natural Fiber Welding	Corporation	New York, USA
Red Swan Ventures	2	1	Modern Meadow	Venture Capital	New York, USA
Shonai Bank	2	1	Spiber	Bank	Tsuruoka, Japan
Susa Ventures	2	1	MycoWorks	Micro VC, Venture Capital	California, USA
Temasek Holdings	2	2	Bolt Threads, Modern Meadow	Private Equity Firm	Singapore
Tony Fadell	2	2	Modern Meadow, MycoWorks	Investment Partner, Individual/Angel	Paris, France

Investor	Number of Investments	Number of Companies Invested In	Companies	Investor Type	Headquarters
Zygote Ventures	2	1	Bolt Threads	Angel Group	California, USA
3M	1	1	Ecovative Design	Corporation	Minnesota, USA
3M New Ventures	1	1	Ecovative Design	Venture Capital	Minnesota, USA
Activate Venture Partners	1	1	Modern Meadow	Micro VC	New York, USA
Allbirds	1	1	Natural Fiber Welding	Corporation	California, USA
Allen & Company	1	1	Bolt Threads	Family Investment Office, Investment Bank, Venture Capital	New York, USA
Alpha Impact Investment Management Partners	1	1	Ecovative Design	Private Equity Firm, Venture Capital	California, USA
Astanor Ventures	1	1	Modern Meadow	Venture Capital	Brussels, Belgium
Athos Group	1	1	AMSilk	Corporation	Texas, USA
Avant Global	1	1	Modern Meadow	Venture Capital	California, USA
Baillie Gifford	1	1	Bolt Threads	Investment Bank, Venture Capital	Edinburgh, UK
Black Point Group	1	1	Modern Meadow	Venture Capital	Maine, USA
Breakout Labs	1	1	Modern Meadow	Micro VC	California, USA
Breakout Ventures	1	1	Modern Meadow	Micro VC	California, USA
Business Finland	1	1	Spinnova	Government Office, Venture Capital	Helsinki, Finland
Cape Capital AG	1	1	Modern Meadow	Private Equity	Zurich, Switzerland
Cargill	1	1	AMSilk	Corporation	Minnesota, USA
Central Illinois Angels	1	1	Natural Fiber Welding	Angel Group	Illinois, USA
Continental Grain Company	1	1	Modern Meadow	Corporate Venture Capital	New York, USA
Cool Japan Fund	1	1	Spiber	Government Office, Venture Capital	Tokyo, Japan
Cthulhu Ventures	1	1	MycoWorks	Micro VC, Venture Capital	California, USA
Dai-ichi Life	1	1	Spiber	Investment Bank, Venture Capital	Tokyo, Japan
Dave Eisenberg	1	1	Modern Meadow	Investment Partner, Individual/Angel	New York, USA
DOEN Participaties	1	1	Ecovative Design	Venture Capital	Amsterdam, The Netherlands
E.R. Capital Holdings	1	1	AMSilk	Private Equity	N/A
Ebara Corporation	1	1	Spiber	Corporation	Tokyo, Japan
Enmi Kendall	1	1	Modern Meadow	Investment Partner, Individual/Angel	California, USA

Investor	Number of Investments	Number of Companies Invested In	Companies	Investor Type	Headquarters
Eudaimonia Capital	1	1	Modern Meadow	Angel Group, Family Investment Office	Singapore
European Investment Bank	1	1	Spinnova	Government Office, Investment Bank	Luxembourg
Evonik Venture Capital	1	1	Modern Meadow	Corporate Venture Capital, Venture Capital	Hanau, Germany
Fidelity Management & Research	1	1	Bolt Threads	Private Equity	Massachusetts, USA
Francois Kress	1	1	Modern Meadow	Individual/Angel	New York, USA
Francoise Marga	1	1	Modern Meadow	Individual/Angel	New York, USA
Future Tech Lab	1	1	MycoWorks	Venture Capital	Stockholm, Sweden
Hatzimemos/ Libby	1	1	Modern Meadow	Venture Capital	New York, USA
Humboldt Fund	1	1	MycoWorks	Venture Capital	New York, USA
Indian Angel Network	1	1	Kanpur Flowercycling Private Limited	Angel Group	Delhi, India
Innovation Endeavors	1	1	Bolt Threads	Venture Capital	California, USA
Interplay Ventures	1	1	Modern Meadow	Venture Capital	New York, USA
John Legend	1	1	MycoWorks	Individual/Angel	Nevada, USA
Karoly Jakab	1	1	Modern Meadow	Individual/Angel	New York, USA
Key Partners Capital	1	1	Modern Meadow	Investment Partner	Berlin, Germany
Lee Barba	1	1	Modern Meadow	Individual/Angel	New York, USA
LeFrak	1	1	Bolt Threads	Venture Capital	New York, USA
MassChallenge	1	1	Orange Fiber	Accelerator	Massachusetts, USA
MIG	1	1	AMSilk	Venture Capital	Munich, Germany
Mission BioCapital company	1	1	Bolt Threads	Venture Capital	Massachusetts, USA
Mitsubishi UFJ Lease and Finance	1	1	Spiber	Corporation	Tokyo, Japan
Nan Fung	1	1	Bolt Threads	Private Equity	Hong Kong
Natalie Portman	1	1	MycoWorks	Individual/Angel	N/A
Prairie Crest Capital	1	1	Natural Fiber Welding	Venture Capital	Iowa, USA
Senator Investment Group	1	1	Ecovative Design	Hedge Fund	New York, USA
Sequoia Capital	1	1	Modern Meadow	Venture Capital	California, USA
Silicon Valley Bank	1	1	Bolt Threads	Investment Bank	California, USA

Investor	Number of Investments	Number of Companies Invested In	Companies	Investor Type	Headquarters
Singularity University Ventures	1	1	Modern Meadow	Venture Capital	California, USA
Starlight Ventures	1	1	Modern Meadow	Venture Capital	Florida, USA
Steen Ulf Jensen	1	1	Beyond Leather	Individual/Angel	Copenhagen, Denmark
The Draper Richards Kaplan Foundation	1	1	Kanpur Flowercycling Private Limited	Micro VC, Venture Capital	California, USA
The Yamagata Bank	1	1	Spiber	Bank	Yamagata, Japan
Toyoshima	1	1	Spiber	Corporation	Nagoya, Japan
Toyota Boshoku America	1	1	Spiber	Corporation	Kentucky, USA
Trousdale Ventures	1	1	Ecovative Design	Venture Capital	Texas, USA
TSURUOKA SHINKIN BANK	1	1	Spiber	Bank	Yamagata, Japan
Ulu Ventures	1	1	Modern Meadow	Micro VC, Venture Capital	California, USA
Vaekstfonden	1	1	Beyond Leather	State Investment Fund	Hellerup, Denmark
Valor Equity Partners	1	1	MycoWorks	Private Equity, Venture Capital	Illinois, USA
VF Ventures	1	1	Beyond Leather	Venture Capital	Hellerup, Denmark
Viking Global Investors	1	1	Ecovative Design	Private Equity	Connecticut, USA
Wireframe Ventures	**1**	**1**	MycoWorks	Venture Capital	California, USA
WTT Investment	**1**	**1**	MycoWorks	Venture Capital	Taipei, Taiwan

Source: MII analysis on investment activities in companies in MII's company database, based on data from SPEEDA Edge, as well as primary and secondary research.

Have we missed anything? Are you an investor interested in the next-gen material industry? Please contact us via this form.

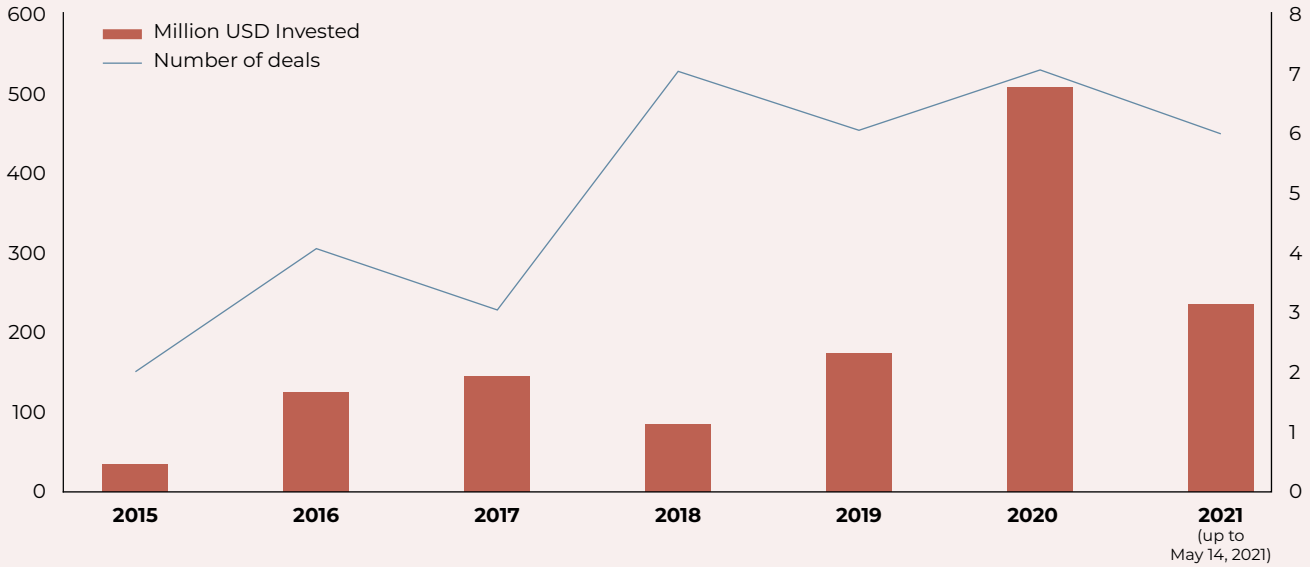
Eva Klabalová & Lucie Trejtnarová sandals made with Malai leather

CAPITAL

Investment in next-gen material innovation reached new heights in 2020. The investment amount in the year of 2020 alone is nearly the same as the previous 4 years combined. Even amid the Covid-19 pandemic, this trend continued.

By mid-May 2021, 4 of the top 10 funded companies have successfully raised new rounds. Investment is expected to further increase as companies mature, demonstrate proof of concept, and scale.

Figure 5.2 Total venture capital invested in next-gen material companies



COMPANIES

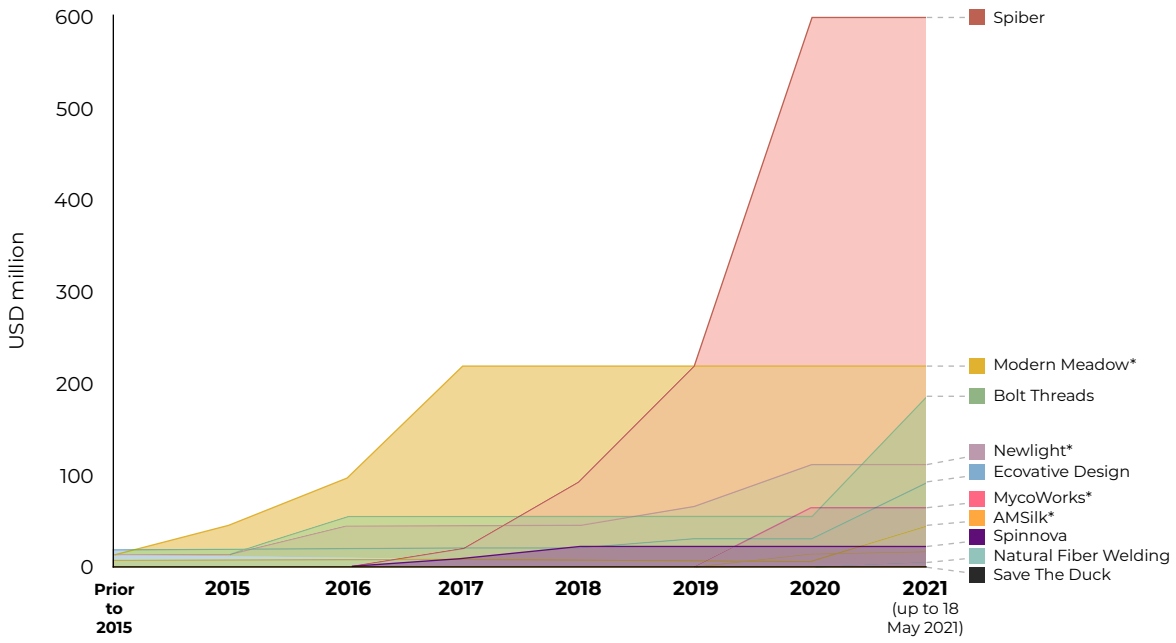
The following are the 10 most funded among the next-gen material companies listed in table 4.1 according to publicly disclosed data.

Table 5.3 Top 10 most funded next-gen material companies (in descending order by total amount raised)

Company	Brief Company Description	Largest round (Million USD) / date	Total amount raised (Million USD) / 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, The North Face Japan, Goldwin, Toyota.	292.9 / Dec 2020	598.8 / Series Unknown
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, Stella McCartney.	123 / Nov 2017	218.1 / Series D
Modern Meadow*	Uses precision fermentation to grow collagen to create animal-free leather primarily for the fashion industry.	130 / Apr 2021	183.5 / Series C
Newlight*	Uses natural ocean microorganisms to make PHB from greenhouse gasses to produce next-gen leather primarily for the fashion industry.	45.1 / Sep 2020	106.6 / Series F
Ecovative Design	Grows mycelium on agricultural waste to produce next-gen leather, primarily for the fashion and self-care industries.	60 / Mar 2021	90.1 / Series D
MycoWorks*	Grows mycelium to produce next-gen leather primarily for the fashion industry. Collaboration with Hermès.	45 / Oct 2020	62.0 / Series B
AMSilk*	Makes spider silk proteins via precision fermentation to produce next-gen silk primarily for the fashion industry.	36 / May 2021	42.3 / Series C
Spinnova	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).	12.3 / Oct 2019	20.7 / Venture Capital
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 Richemont, Steelcase.	13 / Aug 2020	15.0 / Venture Capital
Save The Duck	Uses recycled PET bottles to produce next-gen down primarily for the fashion industry. Collaboration with Dyne.	3.6 / Mar 2021	3.6 / Debt

*Company with one or more rounds of undisclosed amount. Undisclosed amounts are not reflected in the total amount raised in this table.
Source: MII analysis on investment activities in companies in MII's company database, based on data from SPEEDA Edge, primary and secondary research.

Figure 5.4 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 in MII's company database, based on data from SPEEDA Edge, primary and secondary research.

The North Face Moon Parka by Spiber

Bolt Threads

Unlike others in the top 10 funded list, Bolt Threads did not raise most of its funds in the last few years. Its series D round was closed in 2017.

Bolt Threads, originally named Refactored Materials, was founded in 2009 by Dan Widmaier, David Breslauer, and Ethan Mirsky to use biotechnological innovation to create materials. Dan Widmaier initially developed this idea during his Ph.D. in Chemical Biology. The company has since grown to a team of nearly 100 employees.

The company's first material is their spider silk product Microsilk. They then expanded into making alternative leather from mycelium. Transformation takes time. According to Dan Widmaier, Bolt Threads went through 4,000 material sample iterations.

These are some of the reasons venture capitalists are excited about the prospects of Bolt Threads:

"The company has now become more of a tech platform with a portfolio of products rather than just a single material."

"True full loop capabilities from sourcing and manufacturing to commercialization and branding."

"Overall the team has done well in raising capital from both renowned industry & financial investors and having short-term quick wins like product & consortium launches, while waiting for the tech to scale in the longer term."

"...chose to partner with the most exciting luxury and premium brands on the planet to validate potential."

"...focus on aesthetics and performance. Goal is to make brands and consumer journey seamless and frictionless... best analogs are Impossible Foods and Tesla. Bolt is that solution for materials."

Partner also mentioned:

"The founding team has done a lot in giving back to the ecosystem and industry, such as mentoring/advising new material founders, as well as offering residencies for graduate students/scientists. The next step for the company is in scaling up production & supply of materials for larger commercialization."

AMSilk

The largest funding round in 2021 to date (May 2021) is the $35 million series C investment in AMSilk. Novo Growth, the growth equity arm of Novo Holdings, led the round. Kartik Dharmadhikari and Anders Bendsen Spohr, partner and senior partner, respectively, at Novo Holdings, will join AMSilk's supervisory board.

Novo Holdings has also invested in MycoWorks, a mycelium-based alternative leather company.

Dharmadhikari explained what makes AMSilk stand out, "AMSilk's technology has the potential to revolutionize a number of industries and be part of the decarbonization push needed to overcome the biggest environmental challenges of our time."

AMSilk is said to be the world's first industrial supplier of synthetic silk biopolymers. The financing will help the company expand into new markets. The silk biopolymers are suitable for high performance sports apparel and biomedical applications, including medical implants. The materials can be fully recycled and are 100 percent biodegradable. AMSilk offers its innovative range of high performance Biosteel fibers for textiles and industrial applications worldwide and has announced collaborations and partnerships with world leading brands like Adidas and Airbus. The organic high performance material has multiple applications.

6. INDUSTRY BRANDS

OVERVIEW

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

Industry Brands can play multiple important roles in the ecosystem, including funding both 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 acceleration of commercialisation and scale-up production of next-gen materials to replace their conventional counterparts.

This section reviews fifteen representative brands in the fashion, automotive, and home goods industries to assess opportunities available to material innovators.

Table 6.1 Involvement of industry brands in material innovation

Brand	Revenues (FY2020)	Industry	Animal-based Materials used	Actions done with respect to material innovation		
				Internal R&D	Investment	Partnership
Adidas	approx. USD 24.1 billion	Fashion	Leather, Wool, Silk, Down	✓		✓
	• Launched a shoe made from synthetic silk biopolymer Biosteel in partnership with AMSilk. (November 2016) • Collaborated with Stella McCartney to create a tennis dress from spider silk developed by Bolt Threads. (July 2019) • Partnership with Parley to produce 15 million pairs of shoes using plastic waste from oceans, representing approximately 4% of all pairs produced in 2020. • Partnership with Bolt Threads to use the mycelium-based leather Mylo in a sneaker model. (April 2021) • Plans to launch a plant-based shoe from using materials based on algae, eucalyptus trees, and natural rubber. (April 2021) • Partnered with Allbirds to produce an ultra-green shoe with 70% Adidas's recycled primegreen polyester and 30% natural Tencel, a material produced from wood pulp. (May 2021)					
Nike	USD 37.4 billion	Fashion	Leather, Wool, Down	✓		✓
	• Launched the "Space Hippie" footwear collection with sneakers created from 85–90% recycled polyester yarn and foam. (June 2020) • Launched the "Cosmic Unity" collection with a basketball shoe produced from 25% recycled material and apparel collection with over 95% recycled and/or organic content. (February 2021)					

Brand	Revenues (FY2020)	Industry	Animal-based Materials used	Actions done with respect to material innovation		
				Internal R&D	Investment	Partnership
H&M	approx. USD 21.8 billion	Fashion	Leather, Wool, Silk, Down			✓
	• "Conscious Exclusive Collection" used Orange Fiber made from citrus juice by-products to create a cellulose silk fabric, Piñatex pineapple leather, and BLOOM Foam, a flexible algae-based foam. (April 2019) • Collaboration with Vegea to use its leather made from grape wine waste to create handbags. (February 2021) • Partnered with sustainable footwear brand Good News to create footwear made from Bananatex, a durable, waterproof material made with banana fibers. (April 2021)					
Stella McCartney	approx. USD 55.0 million*	Fashion	Wool, Silk, Down			✓
	• Partnered with Bolt Threads to use its precision-fermented spider silk protein thread in apparel. (July 2017) • Partnered with Aquafil to use Econyl regenerated nylon, made from waste fabrics and fishing nets, for apparel and handbags. (June 2017) • Used KOBA bio-based fur, made from recycled polyester and plant-based plastic, to replace animal-based fur. (October 2019) • Released prototype bag (2018) and apparel (2021) from Mylo mycelium leather in partnership with Bolt Threads. • Used Re.Verso, a recycled cashmere made from post-factory cashmere waste. (April 2017) • Partnership with Evrnu and Adidas to use NuCycle, a material made from liquefied cotton waste. (July 2019)					
Gap	USD 13.8 billion	Fashion	Leather, Wool, Silk, Down	✓		✓
	• GAP's activewear brand Athleta used sustainable fibers (including recycled polyester and nylon) in 60% of its materials as of 2019. The sportswear also included the material Econyl - a 100% regenerated nylon fiber made from fishing nets - through partnership with Aquafil. (April 2019) • Launched the internally developed fabric H2Eco made from waste from landfills in swimwear products under the brand Athleta. (April 2019)					
PUMA	approx. USD 6.3 billion	Fashion	Leather, Wool, Silk, Down			✓
	• Partnered with First Mile to launch a sportswear collection using recycled plastic bottles. (March 2019) • Apparel and shoe collections with recycled polyester and cotton from textile industry waste. (April 2021)					
Patagonia	approx. USD 800 million*	Fashion	Leather, Wool, Silk, Down	✓		✓
	• Partnership with Bolt Threads to create jackets from spider silk. (May 2016) • Partnered with TENCEL to use lyocell fiber as an alternative to viscose rayon. (October 2016) • Partnership with Bureo to develop NetPlus material from discarded fishing nets for use in hat brims, sunglasses, surfboard fins. (July 2020) • Launched a jacket with PrimaLoft's recycled polyester insulation. (March 2021)					
Fossil	USD 1.6 billion	Fashion	Leather			✓
	• Kier Tote bag from cactus leather in partnership with Desserto. (April 2021) Fossil plans to expand the use of Desserto's leather to its men's collection to be released in fall 2021. • Skagen brand watch straps from next-gen leather made from mulberry bark, cork, and apple; over 50% recycled materials in clock faces. (April 2021)					

Brand	Revenues (FY2020)	Industry	Animal-based Materials used	Actions done with respect to material innovation		
				Internal R&D	Investment	Partnership
Ralph Lauren	USD 6.2 billion	Fashion	Leather, Wool, Silk, Down		✓	✓
	• Minority investment in Natural Fiber Welding, a company that makes plant- and natural fiber-based materials. (August 2020) • Partnered with Aquafil to use Econyl material - made from consumer waste including fishing nets, industrial plastic waste, and fabric scraps - in selected styles (2020). • Use of recycled polyester made from fiber derived from waste plastic bottles in more than 100 styles. (2020) • Partnered with PrimaLoft to use its down alternative ThermoPlume, made from recycled plastic bottles, as insulation for jackets. (October 2020)					
BMW	approx. USD 98.2 billion#		Leather, Wool			✓
	• Partnered with Aquafil to use Econyl material, made from recycled fishing nets and other nylon waste, in headliners and floor mats of selected vehicle models. (February 2016)					
Bentley	approx. USD 2.5 billion		Leather, Wool			✓
	• Partnership with Vegea to use grape leather in car interiors. (July 2019)					
Mercedes Benz	approx. USD 119.5 billion#		Leather, Wool			✓
	• Partnered with Miko to use Dinamica microfiber, made from textiles and PET bottles, in the interior of certain vehicle models. (January 2021) • Partnered with Aquafil to use Econyl material, made from recycled fishing nets and other nylon waste, in floor mats of vehicles. (October 2020)					
Volkswagen	approx. USD 270 billion		Leather			✓
	• ”AppleSkin” Apple leather developed in partnership with Apple Nine Alliance. (April 2019)					
Ikea	approx. USD 28.2 billion	Home goods	Leather, Wool, Silk, Down	✓		✓
	• Partnered with H&M group and Stora Enso to develop a new textile fiber based on cellulose from wood. (December 2018)					
Herman Miller	USD 2.5 billion	Home goods	Leather, Wool	✓		✓
	• Joined the NextWave plastics initiative as a founding member to develop the first global network of ocean-bound plastic supply chain. (2018) • Introduced a collection made from ocean-waste plastic and biodegradable polyester. Available as a material for their seating products. (2021)					

*Full year 2019 figures. #Part of the company’s business only.
Source: SPEEDA Edge

Many industry brands have specific, publicly disclosed targets and pledges to attain measurable improvements in sustainability. These new targets create concrete opportunities for material innovators.

Table 6.2 Sustainability commitments from industry brands

Brand	Current Sustainability Commitments	Future Sustainability Commitments
Adidas	• Issued a sustainability bond of EUR 500 million (USD 585 million) in Sep 2020 to be used for investments into more sustainable materials and processes. • 71% of all polyester used for their apparel and footwear was recycled polyester in 2020. • More than 60% of all Adidas products will be made from sustainable materials for the first time in 2021.	Replace virgin polyester entirely with recycled polyester by 2024.
Nike	• 78% of Nike, Jordan, and Converse shoes contained some amount of recycled materials as of May 2021. • Produces footwear from recycled polyester from over 1 billion post-consumer plastic bottles annually. • Uses recycled and organic cotton (10% of total cotton volume as of 2020) and recycled polyester (26% of total polyester volume as of 2020). • 59% sustainable materials used in Nike apparel as of 2020. • 29% sustainable materials used in Nike footwear as of 2020.	Increasing the use of low-carbon materials to 50% of all key materials (polyester, cotton, leather, and rubber) by 2025.
H&M	• Recycled polyester from an equivalent of 1.1 billion PET bottles in 2020 (537 million in 2019). • 64.5% of materials were recycled or sustainably sourced in 2020. • Sourcing of recycled materials more than doubled to 5.8% of total materials in 2020 (from 2.2% in 2019).	Use 100% sustainable or recycled material to manufacture products by 2030.
Stella McCartney	• Since its founding, the company has never used animal-based materials such as leather, feathers, fur, and skin. • Started using recycled polyester in 2012.	No products contain animal-based leather, feathers, fur or exotic skin.
Gap	-	Gap's brand Banana Republic has a goal to make 50% of its products with sustainable fibers by 2023.
Puma	-	• Develop recycled material options for leather, rubber, cotton, and PU by 2025. • Over 50% sustainable material content in 90% of PUMA Apparel and Accessories by 2025. • 90% of all footwear to contain at least one sustainable component by 2025. • Increase the use of recycled polyester in apparel and accessories to 75% by 2025.

Brand	Current Sustainability Commitments	Future Sustainability Commitments
Patagonia	Capilene Cool Tech t-shirt collection made from 35-100% recycled material; Baggies shorts collection from 100% recycled nylon.	Produce all apparel products from 100% recycled, reclaimed or renewable resources by 2025.
Fossil	-	Include sustainable design elements in over 50% of products sold globally by 2025.
Ralph Lauren	-	Source 100% of key materials sustainably by 2025.
BMW	In Feb 2021, BMW announced that its British car brand MINI will stop offering leather interiors in all new models by 2021.	In Aug 2020, the company announced the switch to vegan leather in all new 5-series models.
Bentley	-	-
Mercedes Benz	-	-
Volkswagen	-	-
IKEA	• Recycled polyester used in 83% of home textile products in 2020 (~59% in 2019). • As of May 2021, 60% of materials are renewable and 10% are recycled.	Use only renewable or recycled materials in products by 2030.
Herman Miller	-	-

Source: SPEEDA Edge

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"Globally, people are becoming more aware of the impacts their everyday choices can have on the environment. We've seen that small, thoughtful decisions and initiatives can have big impacts and the move toward animal-free fashion around the world is one example of this."

- Alyssa Whited, Global Director of Marketing, Call It Spring

Natural Fiber Welding leather Mirum™ colored sheets

INSIDER INSIGHTS

A key takeaway from the Hanson-Wade/Material Innovation Initiative Bio-Based Alternative Textiles Innovation Summit (March 31 & April 1, 2021) is the need for honesty and transparency from material innovators with brands, consumers, and investors. With any new technology, time and patience are needed for development. Material companies need industry brands to partner with them in developing and improving the aesthetics and performance of next-gen materials to match and eventually to surpass their animal-based counterparts.

With better expectation management, industry brands can work with material companies to overcome the inevitable challenges. In this section, we consider solutions from the perspective of designer, manufacturing partner, and industry brand.

A Designer's Perspective

There is definitely a wow factor when you can tell your customers that your bag is made from pineapple, mango, cactus, corn, or apple. And Jessica Kruger, founder of London-based luxurious vegan accessories brand LUXTRA, has worked with many of these next-gen materials.

LUXTRA bag made with Piñatex®

There are many less-fun moments, however. These might occur when testing a material, only to find that it cracks and disintegrates when out in the real world. Or perhaps a promising material is only available in three colors. Or maybe it's when the trusted manufacturing partner that has decades of working with real leather has no idea how to work with the new material and the prototypes look terrible. These are just a few examples of Jessica's struggles with innovative materials.

Jessica's wish list for the perfect material:

1. The perfect material is circular. Brands and designers endure the initial pain of working with an unfamiliar material to create more sustainable and environmentally friendlier products. If this box cannot be checked and if sustainability claims are limited (e.g. because the backing of a material is primarily plastic), there is much less incentive to work with the material.

2. The perfect material has high marks in performance. This includes good scores from the Martindale abrasion test, for example. The material can't crack or disintegrate with use, and the surface should be smooth and appealing: no chunks that make the material surface uneven. Durability is also key.

3. The perfect material is beautiful. Aesthetics matter to designers. But for a material to really start to compete with the mainstream options, brands will want to see choice. A range of colours, finishes (glossy, matte), textures (smooth, pebbled) and emboss-ability (i.e. to ensure stamped logos will not rub off or flatten out with time).

Other practical concerns include lead time, location of the material (to minimise the carbon footprint), and price.

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"Designers are looking for beautiful materials that perform - don't crock or crack, can withstand daily abrasions and the occasional spill - and are available for sampling with production quantities ready to ship within the usual fashion production lead times.

We also like to customize products to differentiate from other brands. That might include 'stamping' a logo or printing a pattern onto the material. These are services that most brands are accustomed to receiving when working with a supplier.

Brands will not want to pay more than they do for the animal-derived material. Every brand has material budgets. But I would say it's important for brands to make a commitment to material innovators. One of the things that fashion should do better (and there are many!) is to do more partnering with material makers. Erratic orders from brands make it difficult for material companies to employ people consistently and safely. At this moment when we have so many innovators on the cusp of changing the material world, they could really use this commitment from brands."

- Thomasine Dolan, Fashion Design Specialist of MII

A Manufacturer's Perspective

Most industry brands have manufacturing partners, including mills and factories, that they rely on to execute a design. Significant initial investment of time and resources is required to test and tweak new materials to make them work with existing machinery, with the skills and experience of workers, and with sourcing procedures.

Veshin Factory. Xiao Wei, Executive Director (left) and Hongliang Yu, Co-owner (right).

This can be a bottleneck to transitioning into next-gen materials. Joey Pringle, co-founder of Veshin Factory, is on a journey to turn a decade-old factory specialising in manufacturing premium leather goods for luxury brands into a vegan factory.

After a year of testing and working with many next-gen materials, including cactus leather, and turning them into end products for 6 brand clients, Joey knows that collaboration is key. It is important to have a manufacturing partner who is willing to sit down with the material innovators and the brands to consider the best ways to work with innovative materials.

Traditionally, the industry operates in two-way relationships. Brands order directly from material suppliers and send directly to the manufacturer. However, with novel materials this often creates friction. Joey is trying to make this a three-way relationship by bringing brands, material innovators, and manufacturers together.

In order to help next-gen materials scale quickly, Joey is taking the initiative to support his clients (brands) by doing the groundwork for them. From the very beginning, Joey invests time and resources to test and experiment with a next-gen material. Using his in-depth knowledge and experience with product specifications required by the brands, Joey can provide feedback and work on re-iterations with material innovators early in development. Many pain points and risks associated with using a new material, both from the brand and the material supplier perspectives, can be mitigated by a manufacturer with expertise with that material in the relationship. With today's push for a more ethical and transparent supply chain, having a trustworthy three-way relationship also enables brands to confidently educate their consumers about the materials they use and the manufacturing process that has gone into making its products.

A Sourcing Perspective

"Fashion brands recognize the trend toward more sustainable and animal-free materials. We have met with forty fashion, automotive, and home goods brands, and all but two are actively searching for next-gen materials to integrate into their supply chains.

The current materials industry does not yet produce sustainable options at scale that meet brands' performance, aesthetics, and price requirements. When we help brands source these next-gen materials, we encounter very few existing options that meet a brand's specifications and hit their sustainability goals. We continue to reiterate that perfection cannot be the enemy of good. In other words, although we are not quite there on 100 percent cradle-to-cradle sustainability, moving to next-gen raw materials will have significant positive environmental impacts.

Additionally, although brands are excited to be pioneers and leaders in utilizing these materials, they are learning that it requires time, effort, and collaboration with innovators to form a true partnership. Other options are brands that are conducting their Research and Development in-house. However, as most are discovering, the time, people, and expense needed for that option are better found out of house with innovators in all stages of development."

- Jacqueline Kravette,
Chief Brand Officer of MII

PART C: OTHER DRIVING FORCES

7. ADVANCEMENTS IN SCIENCE AND TECHNOLOGY

Innovation in the next-gen materials industry is fueled by recent advancements in science and technology. Deep tech innovation, aimed to replicate the intricate structure and composition of animal-derived materials, is poised to come to market shortly. Many of these innovations are founded on platform technologies that rely on versatile approaches to material development, and will have broader reach than the design of a one-time material composition. Key innovators are building intellectual property portfolios in these technology spaces that will be essential to their long-term success. Below are a few examples of recent advances in science and technology that are paving the way for next-gen innovation.

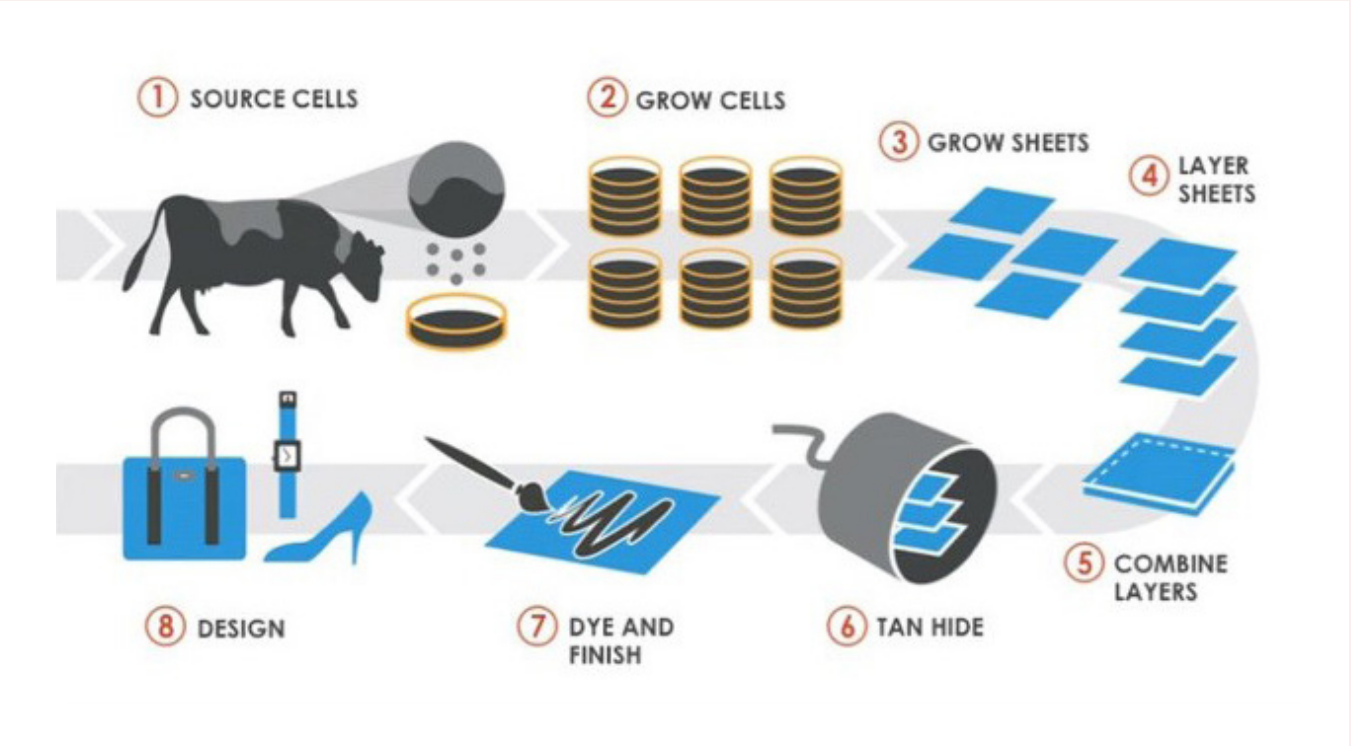
BIOTECHNOLOGY:

- **Precision fermentation.** Precision fermentation uses microbial hosts as factories to produce target compounds. Fermentation has been used since early humanity for brewing alcoholic beverages or fermenting foods, but recent advances in biotechnology have enabled this process to apply to a wide range of industries. Recombinant DNA technology, or the use of genetic engineering to produce foreign molecules in microbes, was first applied to high value, low volume biomedical products such as insulin in the 1980s.[16] However, recent advances in genome sequencing and editing, alongside cell culture process optimization, have led precision fermentation to be used to produce lower value, high volume products such as alternative food protein. Now, a biotech revolution in materials is setting the stage for commercial production of proteins, biopolymers, and chemical precursors for next-gen material formulations.

- **Tissue engineering and bioprinting.** Further along the development pipeline, we see cell-based technology take shape in the form of lab-grown tissues. Similar to precision fermentation, tissue engineering first took hold in the biomedical industry. The first tissue-engineered product for skin burn treatment was commercially available in 1998.[17] Since then, lab-grown meat has entered the marketplace, where the muscle that comprises beef, chicken, or seafood can be grown in cell culture medium in a laboratory. Lab-grown leather applies this same technology to materials. (See Figure 7.1) Bioprinting, or the use of 3D printing to create living tissue structures, may soon find commercial relevance in replacing animal materials. Over 10,000 scientific publications and 9000 patents in the tissue engineering field have been published in the last 20 years.[18]

- **Mycelial growth.** Unlike the yeast (a type of fungi) cells used in the aforementioned precision fermentation processes, multicellular fungi have paved the way for a unique subset of materials derived from the root-like structure of mycelium. This fast-growing, fibrous structure first found applications as an alternative to styrofoam packaging material,[19] and is now taking hold as a replacement for meat or leather. With at least seven innovators employing this technology, a diverse intellectual property landscape is emerging surrounding mycelium.[20]

Figure 7.1 Lab-grown Leather Process



Source: Material District, "Help the Planet with lab grown leather? 2," materialdistrict.com, Mar 31 2015. https://materialdistrict.com/article/help-the-planet-with-lab-grown-leather/help-the-planet-with-lab-grown-leather-2/#moved

BIOBASED CHEMISTRIES:

- **Novel composites technology.** Outside of the biotech boom, there have still been advancements in more traditional aspects of materials science such as composites manufacturing. Natural Fiber Welding combines novel bio-based resin chemistries to weld natural fibers, producing composite structures that can be tuned for specific performance requirements. Based on patented technology licensed through the US Air Force, this military-grade tech will soon be consumer-facing in the form of next-gen leather.[21]

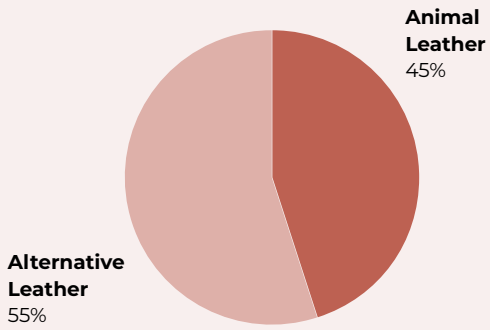
- **Bioplastics.** Although petroleum-derived plastics have created a host of environmental problems, the versatility and range of properties offered by synthetic polymers such as polyester and polyurethane are unrivaled in the materials industry. Innovation in bio-derived plastics and/or plastics that are biodegradable has enabled next-gen materials to reduce their reliance on fossil fuels and to prevent the accumulation of plastic waste in the environment. For example, Dupont's Sorona, a biobased polyester, is used in the formulation of next-gen fur, and bio-based polyurethane is used as a coating or binder in several next-gen leather compositions. The bioplastics market is expected to grow to $26B by 2027, with textiles occupying the second-largest market share aside from packaging.[22]

8. CONSUMER PREFERENCE

Although consumers appreciate the quality of animal-based materials, their impact on the environment and on animal welfare continue to give rise to the desire for high quality alternatives more in line with consumers' values. This expectation of values orientation in fashion choices is especially prominent among younger generations.[23]

As the bulk of innovation in next-gen materials is in leather alternatives, the Material Innovation Initiative undertook a study of U.S. consumers to obtain preliminary data on consumer interest in and reasons for purchasing leather alternatives, as well as consumer perceptions of product attributes, openness to different production technologies, pricing, and preferences for message framing.[24] Currently, little data exists regarding consumer acceptance of any next-gen materials. Our exploratory study begins a research agenda to better understand consumer attitudes and behavior towards new materials that are high performance, more sustainable, and animal-free.

Figure 8.1 Material preference between animal leather and alternative leather



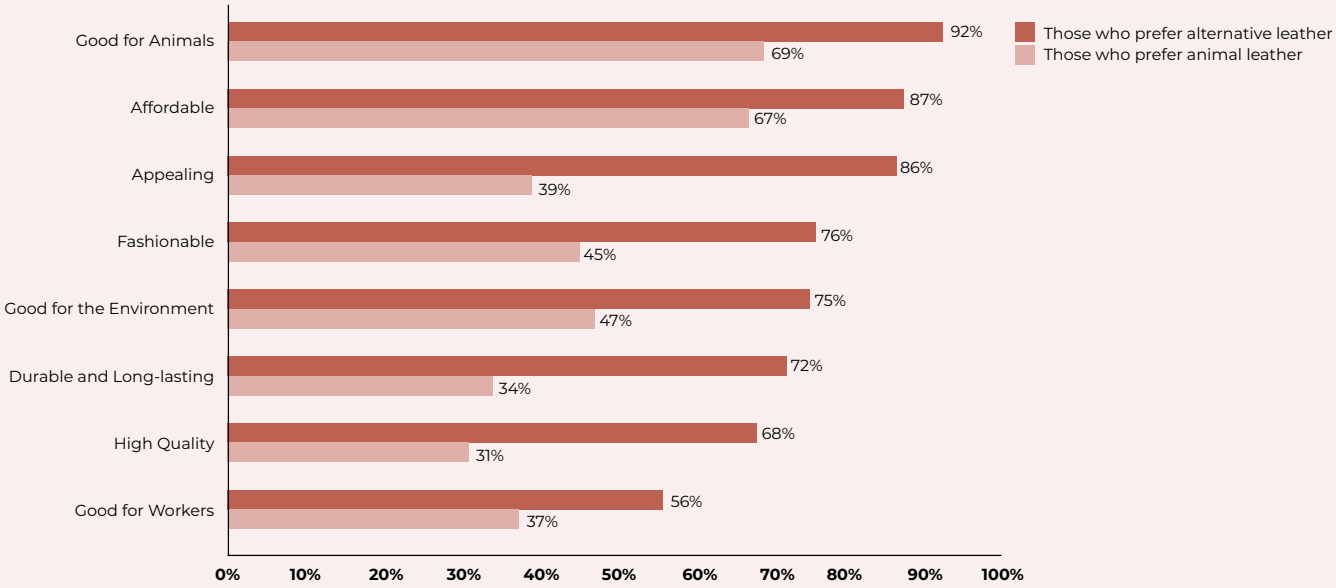
MII's exploratory study examined U.S. consumer purchasing preferences for leather and leather alternatives. We collected survey responses from a sample of 519 individuals across the U.S. through Amazon Mechanical Turk. We segmented consumers by whether they preferred animal leather or leather alternatives. 45% of respondents preferred animal leather while 55% of respondents preferred alternative leather. (Figure 8.1)

Those who preferred animal leather (45%) appreciate the high quality, durability, and authenticity of animal leather and enjoyed the soft feel, smell, and breathability. Those who preferred leather alternatives (55%) appreciate the altruistic benefit for animals and the environment and enjoyed the affordability and low maintenance aspects of alternative leathers. Being animal-free and affordable were the top attributes of leather alternatives for both consumer segments.

Even among U.S. consumers who prefer animal leather, at least 45% consider alternative leather more fashionable and better for the environment. As expected, consumers who prefer alternative leather had higher overall rates of agreement in all categories: over 75% consider alternative leather good for the environment and fashionable, 87% see it as affordable, and 92% as good for animals. (Figure 8.2)

Figure 8.2 Percentage of Participants who agreed with each attribute statement about alternative leather

Note: The percentage includes both participants who 'agreed' or 'strongly agreed' with each statement.



We then examined how open each group was to purchasing materials made using different technologies and ingredients. We tested consumer preferences for (1) acrylic or polyester materials; (2) plant-based fibers; and (3) materials grown from animal cells in a factory.

LEATHER MADE OUT OF ACRYLIC OR POLYESTER MATERIALS

Among those who prefer animal leather:
- 71% were open to purchasing
- 17% were enthusiastic about purchasing

Among those who prefer alternative leather:
- 92% were open to purchasing
- 50% were enthusiastic about purchasing

LEATHER MADE OUT OF PLANT FIBERS

Among those who prefer animal leather:
- 80% were open to purchasing
- 25% were enthusiastic about purchasing

Among those who prefer alternative leather:
- 96% were open to purchasing
- 67% were enthusiastic about purchasing

REAL LEATHER GROWN FROM ANIMAL CELLS IN A FACTORY

Among those who prefer animal leather:
- 80% were open to purchasing
- 37% were enthusiastic about purchasing

Among those who prefer alternative leather:
- 73% were open to purchasing
- 34% were enthusiastic about purchasing

This research indicates a strong market for next-gen leathers even among those who prefer animal leather. Both consumer segments preferred leather made from plant-based fibers and leather grown from animal cells over polyester and acrylic-based leather. One of the main reasons for preferring animal leather over alternative leather was a concern about quality. As alternative leathers continue to improve in performance, it is likely that the market will continue to grow.

As the expected price for next-gen leathers is higher than animal-based leathers, we also asked consumers how much more, if anything, they would be willing to pay for alternative leathers that are animal-free and more sustainable. Among those who prefer animal leather, 56% would not pay more, 25% would pay 10% more, 9% would pay 25% more, 9% would pay 50% more, 2% would pay 100% more. Among those who prefer leather alternatives, 31% would not pay more, 39% would pay 10% more, 22% would pay 25% more, 6% would pay 50% more, and 2% would pay 100% more.

Among those who prefer animal leather:

- Overall, 44% would pay more
- 20% would pay at least 25% more

Among those who prefer alternative leather:

- 69% would pay more
- 30% would pay at least 25% more

This survey suggests that consumers are willing to pay more for products that align with their values but still meet their aesthetic and performance needs. Surprisingly, 44% of consumers who prefer animal leather are willing to pay more for next-gen leather products and 20% of them are willing to pay at least 25% more than they are currently paying.

Jo-Anne Vernay made with Piñatex® by Ananas Anam

These results provide a first look at U.S. consumers' preferences for alternative leathers and show a clear preference for next-gen leather over animal-based leather. As consumers who preferred animal-based leathers did so because they were perceived to have higher quality and performance attributes, we expect these consumers will be open to switching to next-gen leathers when they are at price, quality, and performance parity.

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Our study showed that consumers who prefer animal-based leathers do so because animal leathers are seen as having higher quality and performance attributes. These consumers will be open to switching to next-gen leathers when they are at price, quality, and performance parity. Most consumers will even be willing to pay more for products made from next-gen materials that align with their values.

9. REGULATORY CHALLENGES AND OPPORTUNITIES

INCREASED CONCERNS ABOUT SUSTAINABILITY

More and more people are concerned about sustainability in their fashion purchases. Consumers, especially Millennials and Gen Z, are expressing desires to purchase more sustainable products. In a McKinsey & Company consumer research study of U.K. and German consumers conducted in April 2020, 67% of those surveyed consider the use of sustainable materials an important purchasing factor, and 63% consider a brand's promotion of sustainability in the same way.[25] Similarly, Lenzing Group, a global leader in sustainably produced wood-based specialty fibers, conducted a consumer perception study in early 2020 of 9,000 respondents across nine countries aged between 18 and 64 on "Sustainable Raw Materials in Fashion and Home Textiles." The majority of respondents, 86%, said that purchasing clothes made from sustainable raw materials is a key component of living a more sustainable lifestyle. 80% of respondents said they frequently purchase products from brands committed to using sustainable raw materials. 40% of respondents said they are willing to pay an average of 40% more for clothing or home textile products with descriptions that reflect sustainability. About 50% of fashion executives in a recent opinion poll indicated that sustainability has become more important during the COVID-19 pandemic.[26] We are seeing this trend in our work with brands. "Out of 40 brands we have met with, 38 are actively looking for more sustainable materials. The brands we have spoken to recognize that consumers want to purchase more ethical products, especially younger generations, and the brands want to get ahead of the trend." Jacqueline Kravette, Chief Brand Officer, Material Innovation Initiative. In addition, investors are increasingly requiring those companies in their portfolios to pass sustainability thresholds.[27] COVID-19 has also pushed governments to do more about sustainability, with many European regional and national authorities tying post-COVID recovery efforts to sustainability objectives.[28]

INCREASED FOCUS ON ANIMAL WELFARE INCLUDING BANS ON ANIMAL-BASED MATERIALS

In the past two decades, concern for animal welfare has brought about an increase in the number of animal welfare certifications, as well as bans on certain husbandry practices and on the production or use of certain animal-based materials. We see this concern for animal welfare continuing especially as the market offers consumers more choices that meet their aesthetic and performance needs and are cruelty-free and more sustainable.

Industry trade associations and independent nonprofits continue to implement animal-welfare standards to comply with increased consumer concerns over the treatment of animals. Examples include the International Wool Textile Organisation (IWTO) Guidelines for Wool Sheep Welfare;[29] Textile Exchange's Responsible Leather, Wool, Down, Mohair, and Alpaca Standards;[30] and Kering's Animal Welfare Standards.[31]

Brands are Increasingly banning the use of certain materials. Burberry, Gucci, and Prada banned the use of fur. Chanel, Diane von Furstenberg, and Mulberry banned many exotic skins, and PVH, which owns Calvin Klein and Tommy Hilfiger, banned angora, fur, and exotic skins.[32] Some luxury brands such as LVMH[33] and Hermès[34]

have expressed their concern for animal welfare by building new production facilities and bringing the production of exotic skins under their control. Hermès is also betting on next-gen mycelium leather through a partnership with MycoWorks.[35]

Fashion shows all over the world are joining brands in banning certain animal materials from the runway. Stockholm's Fashion Week banned fur and exotic skins in fall 2020, London Fashion Week banned fur in 2018, and the Melbourne and Helsinki fashion weeks banned exotic skins in 2018.[36]

In addition, many countries are implementing more stringent animal-welfare regulations or outright banning the production or sale of some animal-based materials. For example, over the past two decades, twenty countries have voted to ban fur production, to prohibit the farming of particular species, or to implement stricter regulations.[37]

LOW REGULATORY BURDEN TO MARKET ENTRY

The main regulatory burdens to market entry for next-gen materials are the standard burdens placed on other materials used in similar applications. The main regulations include restrictions on hazardous chemicals and compliance with flammability standards. In the United States, these regulations include California Proposition 65, Federal Hazardous Substances Act, the Consumer Product Safety Improvement Act, and the Flammable Fabrics Act. The hazardous chemicals restricted by California Proposition 65 and Federal Hazardous Substances Act are not typically used in the production of next-gen materials.

Although some next-gen materials may include genetically modified materials, the restrictions on non-food GM products are much lower than regulations governing GM ingredients for human and animal food. Producers should review the regulations in the country of production and countries of sale of their materials as GM regulations can vary significantly between countries. The United States has one of the more liberal approaches, which focuses on the nature of the end products, rather than the process by which they were produced.[38] It is worth noting that GM cotton has been widely approved for decades and currently comprises 90% of U.S. production[39] and has been the most widely sown GM crop in Mexico for 20 years.[40]

LABELLING RESTRICTIONS

We expect that producers of animal-based materials will challenge the use of tems like "leather" and "fur" for next-gen materials, just as animal-based meat and dairy producers challenge the use of "burger" and "milk" when applied to plant-based foods.[41] The International Council of Tanners has already begun to track labelling restrictions on these terms, stating that "the correct labelling and description of leather and leather products is very important in order to protect both the leather market and consumers against misdescriptions."[42] In May 2020, Italy banned the use of the terms pelle/cuoio (leather) to identify materials that do not have an animal origin.[43] The UNIC, the Italian Tanneries Association, specifically praised the law for the "express prohibition of the use of the words skin and leather, also as prefixes or suffixes, to identify materials not derived from the remains of animals, such as today it occurs with the unorthodox terms eco-leather, vegan leather and the like used for synthetic materials."[44] Because restrictions on the use of "leather" follow the same reasoning as proposed restrictions for "milk" and "burger," we anticipate that such labelling laws will ultimately not survive legal challenges.

Belts made with Viridis®

10. CONCLUSION

This report represents the first time the emerging industry of next-gen materials—high performance and more sustainable alternatives to animal-derived materials—is analysed and presented in a way that aims to inspire different stakeholders to take action.

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. 2020 highlighted that raising animals for their skin, fur, or feathers can be a risky business with low margins and high variability. Going forward, the greatest opportunities lie in developing technology and materials that inherently meet market demand for sustainability, style, and performance.

Of the total 74 companies innovating in next-gen materials, 42 were established since 2014. Thirty of these 42 new companies focus on leather biomimicry.

Investment in next-gen material innovation reached new heights in 2020. The investment amount in 2020 alone is nearly the same as in the previous 4 years combined. Even amid the Covid-19 pandemic, this trend continued. By mid-May 2021, 4 of the top 10 funded companies have successfully raised new rounds. Investment is expected to further increase as companies mature, demonstrate proof of concept, and scale.

Industry brands have taken actions with respect to material innovation through internal R&D,

investments, and partnerships. Many brands also have sustainability commitments to completely switch to, or significantly increase the use of, more sustainable materials by a certain year. Such commitments present more opportunities for material innovators and suppliers.

Acceleration of the next-gen materials industry is fueled by recent advancements in science and technology, by regulatory trends, and by consumer preferences. Deep tech innovation, aimed to replicate the intricate structure and composition of animal-derived materials, is poised to come to market soon. Technologies have the potential to significantly transform the industry by creating materials that meet brands; and consumers' aesthetic, performance, and price needs and that are also more sustainable and animal-free. Technology is already disrupting the materials market and will continue to do so. Those who are quick to adapt have the opportunity to reap massive financial benefits by staking their claim on the materials industry of the future.

As we face potentially dire climate change, this is not the time to take it slow. We need significant investments, partnerships, and more material companies and scientists tackling the issues facing the industry. Collaboration is the path forward. Now is the time to embrace sustainable innovation, both to create a liveable future on Earth and to create a prosperous future for the materials industry.

Let's make the sustainable option the default option.

KD New York Vegetable Cashmere™ sweaters

BONUS SECTION

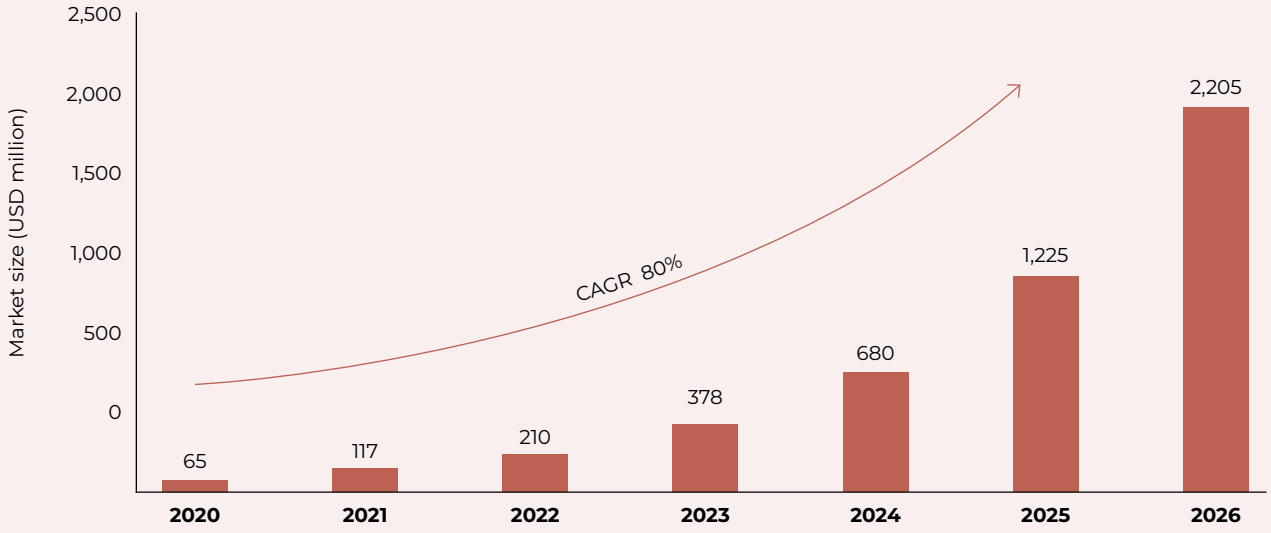
BONUS: PROJECTION OF GROWTH OF THE NEXT-GEN MATERIALS MARKET

We estimate that the global wholesale market size for next-gen materials will be approximately $2.2 billion (USD) in 2026, representing a 3% share of an addressable market of over $70 billion.

In forecasting growth for the next-gen industry over the next 5 years, we look towards the success of other industries such as electric cars, alternative proteins, as well as plastic alternatives to derive a plausible growth rate as new innovative companies begin to come to market. For example, data from International Energy Agency (IEA) suggests that the electric car industry experienced a CAGR of 125% between 2010 to 2015 as consumers demonstrated enthusiasm for sustainable alternatives to transport.[45] While we don't anticipate next-gen materials will grow as quickly, our research suggests that the industry will grow at 80% annually over the next 5 years as new materials begin to enter the market.

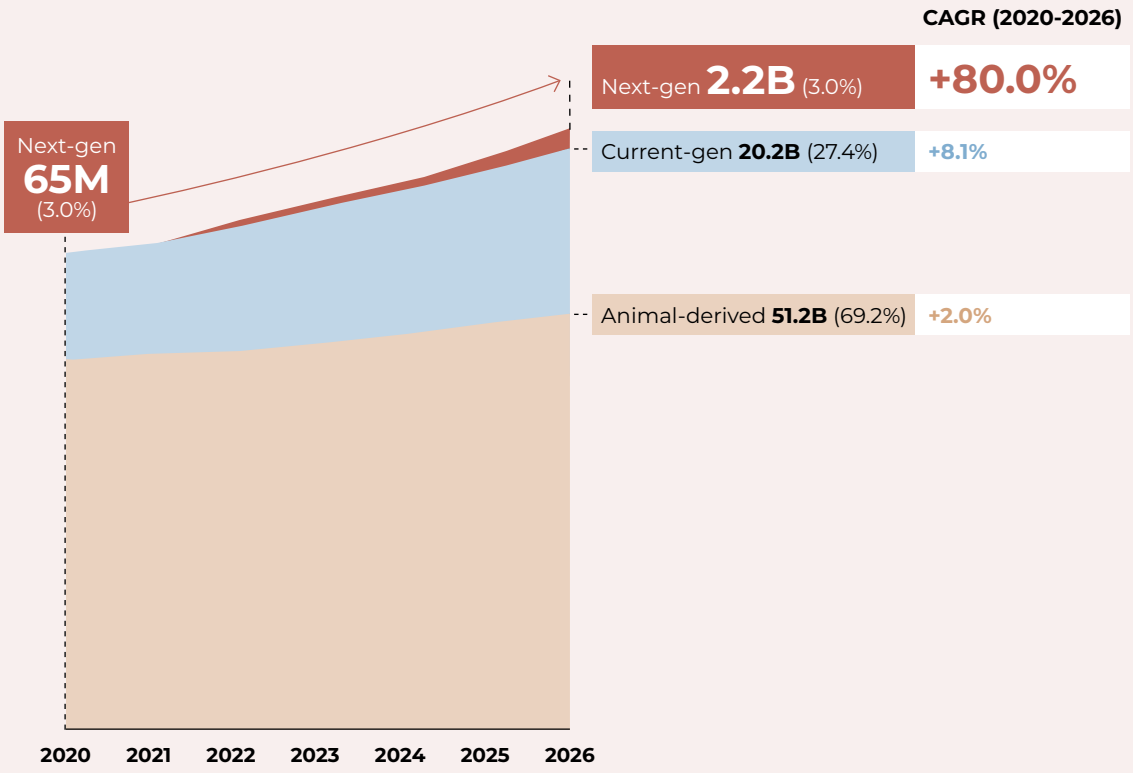
We see the next-gen materials industry as 5-10 years behind where the alternative protein industry is currently. In 2019, McKinsey & Co. estimated the market base for alternative protein at approximately $2.2 billion compared with a global meat market of approximately $1.7 trillion.[46]

Figure 11.1 Projection of growth of the next-gen materials global wholesale market (2021-2026)



Sources: MII / SPEEDA Edge analysis.

Figure 11.2 Next-gen material global wholesale market (billions in USD and market share in %)



Sources: MII / SPEEDA Edge analysis.

IN

WHY IS OUR PROJECTION SO "SMALL"?

Much larger market projections have been made, including this one: The synthetic leather market size is estimated to be USD 63.3 billion in 2020 and is projected to reach USD 78.5 billion by 2025, at a CAGR of 4.4% between 2020 and 2025.[47]

But do these projections compare apples to apples? We use **wholesale** prices in coming up with our market size projection. The market size for end products (e.g., garments in fashion, bedding in home goods, seats in automobiles) is likely at least several times larger. We chose wholesale instead of retail prices, because this analysis is primarily for companies in **material innovation** and for investors looking to invest in these companies. For example, for the leather sub-category, we analysed the leather *material* market, not the leather goods market.

"Current-gen" replacements of animal-based materials that hold a significant share (just over 20% as of 2020) of the addressable market are also not included.

It is worth noting that the total addressable market is a sizable $70 billion. The next-gen material industry is nascent now, but we project it will grow quickly. We applied a compound annual growth rate (CAGR) of 80% between 2020 and 2026.

Forces accelerating the next-gen materials industry include:

A DISRUPTED ANIMAL AGRICULTURE INDUSTRY

The livestock industry has developed revenue streams for every part of an animal (hides, bones, connective tissue, etc.). The hide, for example, is the second most profitable product of the cow.[48] This cost structure creates vulnerabilities, however.[49] When alternatives for one stream of animal product achieve parity in price and quality, the price of other conventional streams will be driven upwards to compensate for the diminishing stream. The alternative protein market—replacement of animal meat, eggs, and milk—is on track to garner as much as 22% of the global protein market by 2035.[50] The cost of these alternative proteins will eventually be 50-80% lower.[51] As more consumers make the switch to alternative proteins, prices of animal-derived materials will rise.

The animal agriculture industry is a break-down or extraction model, whereby a whole animal is grown to be broken down into simpler products that are then sold into different industries and markets. The replacements, whether alternative proteins or next-gen materials, operate by a build-up and build-on-demand model. This opposite approach means at least two things for industries seeking to replace animal-based, break-down models with alternative, build-up models: (1) more efficient feedstock conversion (e.g. 4-11% in the case of animals versus 40-80% in the case of precision fermentation);[52] and (2) a production cycle measured in days, not months or years taken to grow and process animal products.

Moreover, because some companies are creating building blocks, not finished materials, a much wider variety of potential products is possible. A number of companies have expanded from alternative proteins into next-gen materials and vice versa. Others have created building blocks for applications in skincare or medicine.

Spiber is just one example of a company that has expanded its reach.

Although Spiber's initial focus was creating silk and cashmere-like materials, their Brewed Protein can also be woven or knitted into fabric, or processed into non-woven, fur-like or hair-like materials. The raw protein polymer can be dissolved in solvents to make a film or combined with other materials like carbon fiber to make composites. The flexibility of many next-gen material companies to expand across verticals means they are likely to venture beyond the addressable market we estimate here.

Our projection of how fast the next-gen materials industry will grow to replace animal-derived materials (77.4% of the 2020 market), is based primarily on the economics of the animal agriculture industry. The tipping point for a transition toward non-animal-derived foods, ingredients, and materials will occur sooner than generally expected because the current economics of the conventional animal products industry necessitate value-creation from every part of the animal.[53]

THE TURN AGAINST PLASTIC

Consumers are increasingly demanding more sustainable and cruelty free products. The relationship between meat consumption and climate change has increased significantly over the past few years, but fewer consumers have made the logical connection and link animal-derived materials with climate change at this point.

They are currently a lot angrier, and driven to take action, by something else.

The public turn against plastic was not foreseen by scientists or environmental activists. "I scratch my head about it every day," says the Imperial College oceanographer Erik van Sebille. "How is plastic public enemy No 1? That should be climate change."[54]

Regardless, brands are increasingly taking note of this demand from customers. As we have seen in section 6 (in particular table 6.2 Sustainability Commitments of Industry Brands), many brands have made specific commitments to replace, decrease the use of, and/or recycle polyester and other petroleum-based plastics.

Plastic is everywhere. Today's cars are about 50% plastic by volume. More clothing is made from polyester and nylon, both plastics, than from cotton. Plastics also made their way into substituting for animal-derived materials by winning on price—synthesized leather made from petrochemicals sells at wholesale at one-third the price of their animal leather equivalent. In our projection, we call these petroleum-based alternatives (e.g., PU/PVC, acrylic fiber) "current-gen."

Given the consumer turn against plastic, the growth of next-gen materials will be driven partly (or even significantly, in the beginning) by the demand to replace current-gen alternative materials. Because plastic and petroleum-derived materials are much more than cheaper replacements for animal-derived materials, next-gen material companies that develop alternatives to current-gen materials may be looking at a much bigger addressable market than covered here.

THE RELATIVE LACK OF BARRIERS

We are optimistic of a fast and vast shift from animal-derived materials and current-gen alternatives to next-gen materials because of the relative lack of barriers in terms of consumer acceptance and regulatory hurdles.

As discussed in section 6, fashion and automotive brands are willing to switch to next-gen materials once they meet the necessary sensory, tactile, and sourcing specifications for their products. MII has met with 40 major international fashion brands, all but two are actively looking for sustainable and animal-free materials because of customer demand. We are assisting them in sourcing next-gen materials. These brands will likely set the trend for the rest of the industry.

As discussed in section 8, consumers are willing to shift away from animal-derived materials. We anticipate that they will move away from materials made from animals more quickly than from foods made from animals. People don't generally have the same emotional or cultural attachment to materials as they do to food. People don't say: "I just can't give up leather" like they say: "I just can't give up cheese." Consumers don't generally mind technology in their clothes, homes, and cars, and sometimes technology makes those items even more desirable. But consumers are sometimes reluctant to accept novel foods. Consumers also use and purchase animal-free materials already, and in many cases, they are not even aware of the difference. Consumer research data confirms willingness to switch: 55% of American consumers would prefer purchasing a leather alternative and 76% of American consumers are likely to purchase leather grown directly from animal cells without the need to raise and kill an animal.

Perhaps more importantly, as discussed in section 9, the regulatory hurdles are significantly less for introducing a new material to market than for a novel food.

A special note on silk alternatives

Although our analysis assumes a modest 3% future market share for next-gen materials overall, we anticipate that silk alternatives will greatly impact other markets. Microbe-derived spider silk protein, for example, could solve pain points across a variety of industries that cannot currently be addressed by legacy silk.

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ACKNOWLEDGEMENTS

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We'd also like to thank the leading next-gen material companies, industry stakeholders, and investors for their generous input and support.

ABOUT MII

The Material Innovation Initiative is a nonprofit that accelerates the development of "next-gen" (high performance, animal-free, and more sustainable) materials for the fashion, automotive, and home goods industries. Technological innovation and untapped natural materials have the potential to transform the materials industry and solve the enormous environmental challenges it faces.

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, where the planet is saved from pollution and degradation, and where workers are treated fairly and with respect.

MII's team of experts advance innovation in three main ways:

1. identifying and assessing innovative materials and technologies;
2. spurring investments, research, and development to scale innovations; and
3. partnering with brands, retailers, and suppliers to get sustainable materials to market.

We work with scientists, entrepreneurs, investors, material companies, and brands.
Please reach out to us to get involved.

Nicole Rawling
Co-Founder & Chief Executive Officer

Stephanie Downs
Co-Founder & Board Chair

Sydney Gladman
Chief Scientific Officer

Elaine Siu
Chief Innovation Officer

Jacqueline Kravette
Chief Brand Officer

Lisa Lupinski
Chief Marketing Officer

Cortney Busch
Chief Operating Officer

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Fashion Design Specialist

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MII is a nonprofit 501(c)(3) organization, Tax ID 84-3847333.