

SUMMER 2022

FABRICA. WEAVE

CARBON EDITION

碳排放特集



LOW CARBON:
BEYOND CARBON-ZERO

低碳世代：
零碳以外

GREEN MANUFACTURING:
OPTIMIZATION OF
PRODUCTION PROCESSES

綠色製造：
改良生產過程

CARBON INSETTING:
THE 'INSIDE OUT' APPROACH

碳回饋：
從內到外的新趨勢？

CARBON LOOPER BY
H&M FOUNDATION X HKRITA

H&M 基金會 X 香港紡織及成衣
研發中心
「CARBON LOOPER」項目

H&M FOUNDATION
GLOBAL CHANGE AWARD
(GCA)

H&M 基金會
全球變革大獎

the
mills

fabrica
南豐作坊

Welcome to our newsletter!
In each edition we bring
to you interviews, insights
and practical information
about the techstyle
world (companies at the
intersection of technology
and lifestyle).

感謝您閱讀南豐作坊的通訊！
我們將送上不同的訪問與
觀點，以及實用的業界資訊，
帶您投入科技與生活時尚之間的
techstyle 世界。

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THE CARBON EDITION

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此乃中文譯本，如英文版本與此中文譯本有抵觸，
以英文版本為準。

EDITOR’S NOTE

There is an indispensable relationship between
fashion industry and greenhouse gas emissions.
Different stakeholders need to look for their own
innovative solutions to combat the carbon footprint
at different stages of the fashion industry.

In this “Carbon Edition”, innovators from different
sectors of the fashion industry have proved their
determination in combating the carbon issue.
Starting from the production of raw materials in
producing textiles, The Mills Fabrica has talked to
Mango Materials, a biotechnology company that
creates renewable biopolymers from waste
methane gas.

In terms of fashion manufacturing, many brands are
now optimizing their existing production processes
to cut down carbon emissions. The Mills Fabrica has
spoken to Assistant Professor Shauhrat Chopra from
the City University of Hong Kong, whose research
revolves around how the Life Cycle Assessment (LCA)
can enhance the sustainability and resilience of the
environment.

Many businesses nowadays often outsource their
production where they would have limited control
or knowledge of the emissions produced within
their supply chain. This is where the new idea of
“carbon insetting” emerge. By working with various
stakeholders within the value chain, emission
reduction opportunities can be identified and
combated in a collaborative way.

This issue will be concluded by an introduction of
the latest project from the ‘Planet First’ program,
a collaboration between H&M Foundation and
the Hong Kong Research Institute of Textiles and
Apparel to combat the rise in atmospheric carbon
dioxide and global temperature.

編者的話

時裝界與溫室氣體排放息息相關。在時裝生產的不同
階段都會導致不同範疇的碳排放，各方持份者的當務
之急是研發最可以減低碳排放的方案。

在這期《碳排放專題特集》，時裝工業的各個階段中的
創新者，皆展示了他們對減少碳排放的決心。從生產
原材料階段開始，南豐作坊與生物技術公司 Mango
Materials 對談，他們研發出並生產可再生生物聚
合物。

不少時裝品牌試圖在現行的生產過程中減低碳排放
量。南豐作坊邀得香港城市大學助理教授 Shauhrat
Chopra 談談產品生命週期評估 (LCA) 有助提升環境
的可持續性及復原能力。

不少企業的生產過程的不同階段都需要外判，難以控
制或了解整個供應鏈的碳排放程度，業界興起創新的
「碳回饋」方法，與價值鏈當中的各方持份者合作，共
同實現減少碳排放的願景。

本期以 H&M 基金會及香港紡織及成衣研發中心的
Planet First 計劃的最新項目作總結，一同對抗碳排放
及全球氣溫升高的考驗。



Image Courtesy: Unsplash

INTRODUCTION

導言

The fashion industry is famed for its glamour and
greenhouse gas emissions, but the industry alone
is estimated to account for up to 10% of global
carbon emissions (Source: UNEP). Widely believed
to be the third-largest polluter, the fashion industry
emits more carbon than international flights and
maritime shipping combined as no surprise to those
who know that every year, 70 million barrels of oil
are required to produce polyester fibers used in half
of the average wardrobe (Source: Muthu).

The proliferation of fast fashion sees the industry
producing nearly 100 billion new garments a year
(Monash University), and a third end up in the
landfill within the first year of purchase. Fortunately,
consumers (especially Generation Z) have become
more conscious about their purchases, championing
sustainable and ethical brands. No matter how
much a consumer purchases second-hand, rents,
or changes their laundry habits – there is only so
much a consumer can do, so why not start from the
producers instead?

Current sustainable solutions are not enough, and
this calls for solutions to innovate resourcefully –
this includes exploring biotechnology to mitigate
greenhouse gas emissions into new materials,
optimizing production processes, and working
within the supply chain to lower the overall carbon
footprint. Business as usual is no longer acceptable,
and as consumers become savvier about their
purchases, brands are experiencing growing pressure
to comply to the point of “greenwashing”.

時裝界一直以產生溫室氣體而聞名，據估算，此單一
行業的碳排放量就已經佔全球高達 10%，因而被廣泛
指控為世界第三大污染行業，碳排放量甚至比國際航
空及航海運輸業的總和還要多（資料來源：聯合國環
境署）。當然，若你知道自家衣櫃中佔上一半的聚酯
纖維，其實亦需要每年動用 7,000 萬桶石油（資料來源：
Muthu）來生產，一切都變得似乎理所當然。

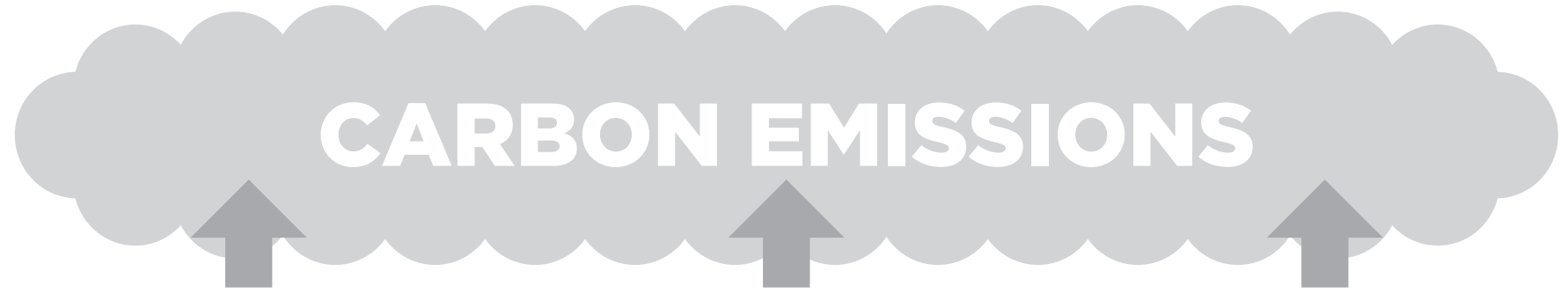
澳洲蒙納許大學 (Monash University) 指出，快時尚
的普及造就每年有近千億件新衣物被製成，當中卻
有多達三分之一會在購買第一年就被丟進垃圾堆填
區。所幸的是，以 Z 世代為首的消費者開始擁抱更高
的購物意識，懂得選擇支持可持續及有道德的品牌。
只是，無論消費者多努力購買二手服飾、使用租衣服
務、及改變洗衣習慣，能做的始終有限，何不從製造
商開始改變呢？

現行的可持續解決方案並不足夠，因而需要創新的
方案，例如探索以生物技術去生產新物料，以減低
溫室氣體排放、改良製造過程，以及從供應鏈入手，
降低整體碳足跡。隨着消費者對消費變得更精明，
品牌為了追趕消費者對環保時裝的要求，很有可能
「漂綠」，表面上宣示自身對環保有付出但事實上卻反
其道而行。



CRADLE-TO-GRAVE CARBON FOOTPRINT

碳足跡的一生

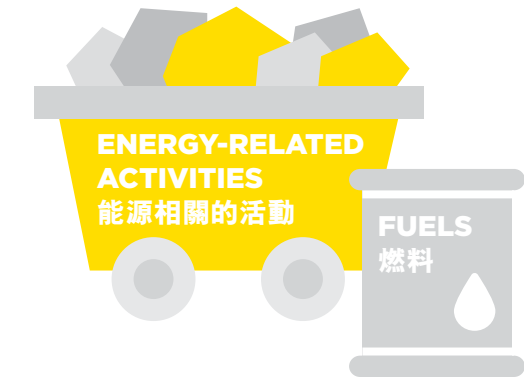


SCOPE 1: BURN
範疇一：燃燒

Direct emissions from sources owned or controlled by the company (e.g. fuel and energy-related activities)

由源頭或企業控制（如燃料及能源相關的活動）而產生的直接排放

ENERGY DIRECT EMISSIONS



SCOPE 2: BUY
範疇二：購買

Indirect emissions from the generation of purchased energy (e.g. electricity, heat, steam)

由購買的能源（如電力、熱能、蒸氣）而來的間接排放

ENERGY INDIRECT EMISSIONS



SCOPE 3: BEYOND
範疇三：更多

Indirect emissions from upstream (e.g. manufacturer, supplier) and downstream (e.g. customers, retailers) activities associated with the organisation

由上游（如生產商、供應商）及下游（如顧客、零售商）等與企業有關的活動而來的間接排放

UPSTREAM INDIRECT EMISSIONS



DOWNSTREAM INDIRECT EMISSIONS



The greenhouse gas protocol categorises emissions created by a company and its value chain into three scopes:

溫室氣體協議把企業及其價值鏈的碳排放分為三大範疇：

+50%

1.2 BILLION TONS OF CO₂

Textile production emits 1.2 billion tons of carbon dioxide per year, and is predicted to increase by more than 50% by 2030

生產紡織品每年排放 12 億噸二氧化碳，更預計會於 2030 年進一步增長 50% 以上

(Ellen MacArthur Foundation)

10%

WORLD EMISSIONS

Fashion accounts for up to 10% of greenhouse gas emissions

時裝界佔溫室氣體排放量達 10%

(World Economic Forum)

3rd LARGEST POLLUTER

Third-largest polluter, fashion emits more carbon than international flights and maritime shipping

時裝界作為第三大污染者，比國際航空及航海運輸業排放更多碳

(World Economic Forum)

200 MILLION TREES CUT DOWN PER YEAR

200 million trees are logged every year to make cellulosic fabric

每年為製造纖維素紡織品需砍伐 2 億棵樹

(Canopy Planet)

1 SECOND = 1 GARBAGE TRUCK LOAD OF CLOTHES TO THE LANDFILL

One garbage truck of clothes is burned or sent to a landfill every second

每秒就有一輛垃圾車份量的衣物被焚毀或送往垃圾堆填區

(Ellen MacArthur Foundation)



Image: Unsplash

LOW CARBON:

BEYOND CARBON-ZERO

Since the Paris Climate Conference (COP21) in December 2015, the Paris Climate Agreement has been set to limit the increase in global average temperature warming to 1.5°C, but the fashion industry may fall short of their contribution based on its current trajectory. In order to meet its goal, the industry requires immediate action to take place and boost sustainability measures.

由 2015 年 12 月的巴黎氣候會議 (COP21) 至今，與會國簽訂的《巴黎氣候協定》已將全球氣溫升幅控制在 1.5°C 之內。可惜根據行業現有的趨勢，時裝界所作出的貢獻可能乏善足陳。為了追上全球協定的標準，業界必需立即採取更嚴格的可持續發展措施。

低碳世代：
零碳以外



The fashion industry emits a whopping 1.2 billion tons of carbon dioxide per year (Ellen MacArthur Foundation). As a result, every stakeholder in the value chain needs to take ownership of their carbon emissions to mitigate their impact on climate change.

Known as a climate-positive solution, innovators have been able to develop design processes that enable greenhouse gas emissions to be captured and stored for use, as well as ones that remove additional carbon dioxide from the atmosphere with the goal of reducing carbon emissions to the point of net-zero.

This requires evaluating the lifecycle and supply chain of a product to identify its footprint and thus areas of reduction to balance out total emissions, before taking one step further in capturing and offsetting carbon emissions. Traditionally fossil-fuel based processes are then substituted with those using renewable energy and low-carbon materials. Nature-based solutions are common, involving the use of plants that hold captured atmospheric carbon materials (e.g. cacti), resulting in a reduced climate footprint. Additional measures can also take place through negative emission technologies such as reforestation and ocean fertilization to permanently remove greenhouse gas emissions from the atmosphere. Technology has also aided the process of creating low-carbon, or carbon-negative, materials. The term refers to the net emissions created, whereby materials or processes remove a larger quantity of carbon dioxide from the air than created in emissions — for example, direct air carbon capture or the use of biochar carbon sequestration to convert carbon dioxide into new valuable resources.

To catalyze decarbonization at an industry level and become a widespread practice requires a proactive and coordinated effort by implementing responsible sourcing standards, better management practices, and utilizing technologies to develop cleaner production processes. As companies learn to track their carbon footprint and mitigate with ways to reduce and offset their emissions, manufacturers need to work on becoming carbon negative by creating and using materials that are low in carbon. Instead of disparaging greenhouse gas emissions, the industry should regenerate carbon dioxide with a new purpose.

Ellen MacArthur 基金會數據指出，時裝界每年的二氧化碳排放量高達 12 億噸。價值鏈中每位持份者亦需要為其碳排放負上責任，各施其法減輕對氣候變化的影響。

為了達至對氣候友善，不少革新者已經研發出各種方法去收集並儲存被排放的溫室氣體，以供日後使用，同步亦能從大氣中消除過量的二氧化碳，以求將碳排放量減低至淨零。

然而，在開始踏上捕捉並抵消碳排放之路前，各產品的生命週期及供應鏈需要先接受評估，以了解其碳足跡，繼而確立減少排放的方案與範圍，才得以平衡總排放量。傳統以化石燃料驅動的工序，可以改為使用可再生能源及低碳物料，當中經常採用的天然方案，包括採用含可吸收溫室氣體植物（例如仙人掌）的物料，以減低碳足跡；或是透過植樹及海洋施肥（即在海洋表面添加養分）等負碳排放技術，永久消除大氣中的溫室氣體。這一系列技術亦有助開發更多低碳或負碳物料，確保物料或產品生產過程中所消除的二氧化碳比排放量更大，淨排放量自然低於零。而最佳例子就是直接從空氣收集碳，或使用生物炭（biochar）進行固碳，有效將二氧化碳轉化為具價值的新資源。

要在行業層面上推動脫碳（Decarbonization），並廣泛實踐，絕對需要整個業界的主動參與及協調。各品牌可採用負責任的採購標準、改善管理法規、及運用科技開發更潔淨的生產程序等。緊隨著各大小機構都開始懂得追蹤碳足跡，並利用減低或抵消排放的方式去緩減對環境的影響力，製造商更應接納或創造更低碳排的物料，盡力共同實現負碳排放。與其只著眼於貶斥排放溫室氣體的弊害，行業不妨再多走一步，協助將二氧化碳再生成全新用途及價值。





MANGO MATERIALS: MAKING CLOTHES FROM METHANE

MANGO MATERIALS： 以甲烷製造時裝

“

The bioplastic created is an excellent source to create polymer and is highly applicable for any industry — in this case, spun into fiber to recreate polyester. At end-of-life, a biopolymer t-shirt or shoe can be biodegraded in up to seven weeks.

生物塑膠顆粒可謂製造聚合物的絕佳原料，更適用於任何行業，舉時裝業來說，顆粒就能精紡成纖維，再製成聚酯纖維。而至無論是生物聚合物 TEE 或是鞋履，它們被丟棄之後，都能在堆填區或海洋中完成生物降解，需時最長 7 星期。

”

Mango Materials is a biotechnology company that creates renewable biopolymers. It is founded by a group of female entrepreneurial scientists and engineers who are global leaders in bio-manufacturing industry. Known for their proprietary technology in creating ‘nature’s plastic’, Mango Materials has created a carbon-negative PHA (Polyhydroxyalkanoates) biopolymer from waste methane that is completely sustainable and closed-loop.

專門生產可再生生物聚合物的生物技術公司 **Mango Materials**，成功以廢甲烷創造出負碳排的微生物聚合 **PHA** 塑膠（Polyhydroxyalkanoates / 聚羥基鏈烷酸酯）。以一群頂尖女性科學家、工程師、兼女企業家為創辦團隊，品牌憑藉此「天然塑膠」的可持續及閉環式特性而聲名大噪，自此在全球生物製造領域坐擁領導地位。

Image Courtesy: Mango Materials



Traditionally, conventional plastics are largely made from petrochemicals, are highly pollutant, and require carbon-intensive production processes. Yet in the exploration for eco-friendly substitutes, many alternatives are expensive and inferior in their mechanisms. Mango Materials has discovered the use of waste methane — a greenhouse gas that is 30 times more potent than carbon dioxide, yet a byproduct from many operations all over the world. Although methane gas has no economic benefits for after-use, the waste gas from U.S. landfills alone can enable Mango Materials to make seven billion pounds of PHA every year.

Partnering with landfills, wastewater treatment plants, and agricultural facilities, the startup co-locates its factory next to existing methane production facilities and uses methane as a feedstock for its biopolymer creation. As a result, the team has revolutionized the plastics industry with a carbon-negative, bio-based alternative that is less harmful to the planet. Mango Materials specializes in the study of PHA biopolymers from methane and its biodegradation under anaerobic conditions.

First using methane as feedstock to methanotrophs, the bacteria have carbon storage properties to digest the biogas and create PHA in powder form before being turned into pellets. The bioplastic created is an excellent source to create polymer and is highly applicable for any industry — in this case, spun into fiber to recreate polyester. At end-of-life, a biopolymer t-shirt or shoe can be biodegraded in up to seven weeks. Whether in landfills or the ocean, the methane released back in the carbon cycle or consumed by marine microorganisms can be recaptured as a resource to produce new biopolymers. So far, the solution has proven to be a low-cost and highly scalable process that can substitute any plastic use.



MANGO MATERIALS

MANGO[®]
MATERIALS

| | |
|--------------------|-------------------------|
| FOUNDED 成立年份 | 2010 |
| HEADQUARTERS 總部 | California, USA 美國加州 |
| FUNDING 資金 | Series A — \$7.5M |
| MANGOMATERIALS.COM | |

WHAT IS THE PROBLEM YOU ARE TARGETING, AND HOW DOES MANGO MATERIALS SOLVE THIS?

Broadly, Mango Materials is working to solve the problems of polluting plastics accumulating in the environment as well as the release of methane greenhouse gas emissions. By utilizing methane to create a valuable product, we provide an incentive for methane capture, thus turning what could otherwise be considered waste into a valuable product and reducing greenhouse gas emissions. Our product, a naturally occurring biodegradable polymer, replaces conventional plastics that persist in the environment.

WHAT MAKES YOUR TECHNOLOGY UNIQUE?

Mango Materials produces the biopolymer polyhydroxyalkanoate (PHA) from methane gas. PHA is unique in that it can replace most conventional plastics and can biodegrade in a wide variety of environments, from wastewater treatment plants to your backyard compost to marine waters. While there are other companies that also focused on the production of PHA, Mango Materials is unique in that we utilize methane, which is often considered a waste, as a feedstock to produce PHA. Using methane allows us to sequester a potent greenhouse gas and enables us to have a lower price point compared to other companies that utilize sugars as feedstock.

傳統塑膠主要以石油化學品製成，能引發嚴重污染，亦需要破密集式排放的生產過程。另一方面，芸芸環保代替品中不少都價格高昂，製作原理更是強差人意。Mango Materials 就在此時發現可以使用甲烷——一種破壞力比二氧化碳大 30 倍的溫室氣體。甲烷向來只屬世界各地許多產業的副產品，且在使用後就再無經濟效益，品牌卻單靠來自美國垃圾堆填區所產生的甲烷量，就成功生產每年 70 億磅 PHA。

Mango Materials 在初創階段就與垃圾堆填區、污水處理廠及農業機構合作，將其工廠設置於會生產甲烷的現有設施旁邊，方便將廢氣轉化成製造生物聚合物的原材料，開展研發生產負碳排的生物性代替品，期望徹底改變塑料行業。其研究目標，主力集中於以甲烷製成 PHA 生物聚合物，以及產品在厭氧環境下的生物降解度，減低塑膠對地球的傷害。

生物化過程運用了具碳儲存特性的甲烷氧化菌（Methanotrophs），並首次以甲烷作為其飼料，讓這種微生物大量消化沼氣，從而產生粉狀 PHA，最後變成生物塑膠顆粒。這些顆粒可謂製造聚合物的絕佳原料，更適用於任何行業，舉時裝業來說，顆粒就能精紡成纖維，再製成聚酯纖維。而至無論是生物聚合物 T 恤或是鞋履，它們被丟棄之後，都能在堆填區或海洋中完成生物降解，需時最長 7 星期。那些在降解過程中重新釋放的甲烷或被海洋微生物消耗的甲烷，最終亦能再被收集成資源，繼而再生產成新的生物聚合物。毫無疑問，此技術不單低成本，同時擴展度高，有效取代各行各業中任何的塑膠用料。

你們所針對的問題是甚麼？而 MANGO MATERIALS 又如何解決此問題？

廣義來講，Mango Materials 是希望致力解決塑膠為環境累積而成的污染，以及甲烷此溫室氣體排放構成的問題。我們希望利用甲烷創造有使用價值的產品，從而鼓勵廠家收集甲烷，好讓原本被視為廢物的東西轉化成有意義的資源，同時亦可減少溫室氣體量。我們的可天然生物降解聚合物，正能取代在地球上存在已久的傳統塑膠。

你們的技術何以與眾不同？

Mango Materials 是以甲烷氣體製造生物聚合物 PHA（聚羥基鏈烷酸酯），其獨特之處在於可以取代大多數傳統塑膠，並能在多種環境中進行生物降解，無論是污水處理廠、你家後院中的堆肥、或是海洋中都沒問題。市場上亦有其他公司專注生產 PHA，但讓 Mango Materials 顯得獨一無二的，是我們成功利用一般被視為是廢物的甲烷作為生產 PHA 的原料，有別於其他公司使用糖為原料，減低生產成本及價格之餘，亦讓我們能夠收服此破壞力強勁的溫室氣體。



HOW CAN MANGO MATERIALS REVOLUTIONIZE THE FASHION INDUSTRY, PARTICULARLY IN FAST FASHION?

Mango Materials can drastically reduce the amount of waste created by the fashion industry. Our PHA biopolymer is used to make fibers that can be turned into clothing. PHA-based clothing can biodegrade at the end of its useful life, drastically reducing the waste generated by the fast fashion industry. Additionally, there has recently been a lot of concern surrounding microfiber shedding and pollution. By using PHA fiber instead of PET-polyester fiber, if shedding does occur, our material will be digested in local wastewater treatment plants and can enter the naturally occurring carbon cycle if improperly disposed of or discarded.

WHAT OTHER IDEAS AND PRODUCTS CAN MANGO MATERIALS BE APPLIED FOR IN FASHION?

In addition to clothing, Mango Materials' biopolymer can be used in the fashion industry in footwear, sunglasses, buttons, jewelry — basically anywhere you see conventional plastics.

WHAT CHALLENGES DO YOU FACE IN COMMERCIALIZING YOUR TECHNOLOGY FOR THE INDUSTRY?

Scaling production and achieving price parity with conventional alternatives is a challenge for any new technology. As we grow our business, our biggest challenge is scaling our process to meet the demands of our customers while also working towards driving down our prices to be competitive with conventional plastics.

MANGO MATERIALS 如何徹底改變時裝業界，特別是快時尚（FAST FASHION）？

Mango Materials 有效減少時裝業構成的浪費。我們的 PHA 生物聚合物能製造服飾所需的纖維布料，而這種 PHA 服飾亦可在其壽命終結時自行生物降解，大大緩減快時尚帶來的浪費。此外，近年坊間亦有關於微纖維脫落、污染等的隱憂及討論，若選用 PHA 纖維代替 PET 聚酯纖維，即使這些纖維真的脫落，亦能被當地污水處理廠處理掉，就算因處理不當而被隨意丟棄，我們的出品仍能進入自然的碳循環之中。

MANGO MATERIALS 的意念與產品還能怎樣應用於時裝領域上？

除服裝之外，Mango Materials 的生物聚合物亦可用作製造鞋履、太陽眼鏡、鈕扣、珠寶等……基本上任何需使用傳統塑膠之處都可以使用。

為業界而將品牌技術商業化時，你們需面對甚麼挑戰？

對任何創新技術來說，要擴充生產規模，同時達至與傳統產品價格對等就是一大挑戰。隨著業務不斷發展，我們正面對最大的挑戰，是如何擴充生產流程以滿足客戶需求，同時盡力降低價格以提升競爭力。



“MANGO MATERIALS CAN DRASTICALLY REDUCE THE AMOUNT OF WASTE CREATED BY THE FASHION INDUSTRY. OUR PHA BIOPOLYMER IS USED TO MAKE FIBERS THAT CAN BE TURNED INTO CLOTHING.”

「MANGO MATERIALS

有效減少時裝業構成的浪費。

我們的 PHA 生物聚合物能

製造服飾所需的纖維布料，

而這種 PHA 服飾亦可

在其壽命終結時自行生物降解，

大大緩減快時尚帶來的浪費。」

ARE BIG BRANDS WILLING TO JOIN FORCES WITH START-UPS LIKE MANGO MATERIALS? WHAT HAS THE JOURNEY BEEN LIKE, AND THE CHALLENGES?

As we have entered the fashion industry, large brands have been very excited to work with Mango Materials to achieve their sustainability goals. It has been a tremendous journey so far, and we have been overwhelmed by the amount of interest in our products from such a wide sector of brands. The challenges are producing enough products to meet all demands and working through supply chains to ensure we meet target specifications for each product.

HOW DO MANGO MATERIALS FIBERS COMPARE TO CONVENTIONAL SYNTHETIC FABRIC? HOW SIMILAR ARE THE CHARACTERISTICS OF PHA COMPARED TO POLYESTER?

While PHAs can be processed in existing manufacturing experiments, and perform similarly to existing fiber materials, PHA is a different molecule than PET. Therefore, it melts, flows, and processes slightly differently. Additionally, due to the difference in the molecule, our products can be consumed by naturally occurring organisms in many different environments. Therefore, the material may appear very similar to the end customer, but its origin and end of life story are completely different.

WHAT VISION AND GOAL DO YOU HAVE FOR THE FUTURE? WHAT IS THE CHANGE YOU HOPE TO SEE?

Our dream is to replace all conventional plastics with biodegradable alternatives so that plastic waste is a non-issue. Our vision is a world where methane emissions are captured and utilized for valuable products, thus drastically reducing greenhouse gas emissions. We hope that Mango Materials can be a catalyst for this change, providing inexpensive plastic alternatives and incentivizing methane capture to reduce greenhouse gas emissions worldwide while simultaneously addressing plastic pollution.

大品牌與 MANGO MATERIALS 一類初創企業合作時，會持多開放的態度？過程是怎樣？有遇上怎樣的困難？

在 Mango Materials 走入時裝界之際，各大品牌都非常樂意與我們合作，共同實現可持續發展的目標。一路走來，至今一直是段浩瀚的旅程，我們產品能有機吸引種類如此繁多的品牌，我們真的受寵若驚。而挑戰則是在於生產足夠的產品以滿足市場需求，並盡力透過供應鏈去確保能切合每種產品的規格標準。

與傳統合成纖維相比，MANGO MATERIALS 的出品如何？PHA 的特性又與聚脂纖維 (PET) 有多相似？

PHAs 雖然能透過現有的製造方法加工生產，質感亦與一般纖維類同，但 PHA 與 PET 卻是不同的分子，其熔化、流動及加工的過程都略有不同。另外，基於分子上的差異，我們的產品可以被更多不同環境中的自然有機體消耗。由此可見，即使我們的產品在消費者眼中非常相似，其起源與終結的故事卻截然不同。

你們對未來有甚麼願景和目標？你希望看到怎樣的變化？

我們的夢想是讓可生物降解的產品取代所有傳統塑膠，讓塑膠垃圾不再是污染問題。我們亦願望建立一個處處都視甲烷為資源的世界，一起去收集所有甲烷，再轉化成有使用價值的產品，大幅減少溫室氣體量。我們希望 Mango Materials 能夠作為這變革的催化劑，成功為市場提供廉價的塑膠代替品，兼推動收集甲烷，以減少全球溫室氣體排放，同時解決塑膠污染問題。

MANGO MATERIALS

CASE STUDY

個案

1

DYECOO



| | |
|--------------------|-----------------------------|
| FOUNDED 成立年份 | 2008 |
| HEADQUARTERS 總部 | Weesp, Netherlands 荷蘭韋斯普 |
| DYECOO.COM | |



DyeCoo has revolutionized the textile dyeing industry with a completely waterless and process-chemical-free solution. Repurposing carbon dioxide from existing industrial waste, DyeCoo can dye any fabric without water, saving up to 32 million liters of water and about 176 tons of processing chemicals per year. Through its proprietary machine, dye is added into the pressurized carbon dioxide tank and can permeate any fabric without additional chemicals or water, yet still creating vibrant colours. The dyed fabric comes out completely dried and does not require any water treatment or produce any wastewater. Short batch cycles, efficient dye use, no wastewater treatment all contribute to significantly reduced operating costs and is scalable at an industrial level.

DyeCoo 以完全無耗水、不使用加工化學品的創新技術，徹底改變紡織品染色行業。品牌能重新利用現存工業廢料所排出的二氧化碳，在毋須用水的情況下為任何紡織物料染上顏色，此舉可節省每年多達 3,200 萬公升水及約 176 噸加工化學品。其研發的專利機器會將染料注入加壓二氧化碳罐中，有效將鮮豔色彩滲透進任何布料中，而毋須額外化學品或水份。染色後的布料完全乾燥，因此亦不用再經過任何水處理或產生廢水。如此快速的生產循環、高效的染料使用、以至零廢水處理，亦大大降低營運成本，自然能成功在業界廣泛推展。

Image Courtesy: DyeCoo



CASE STUDY

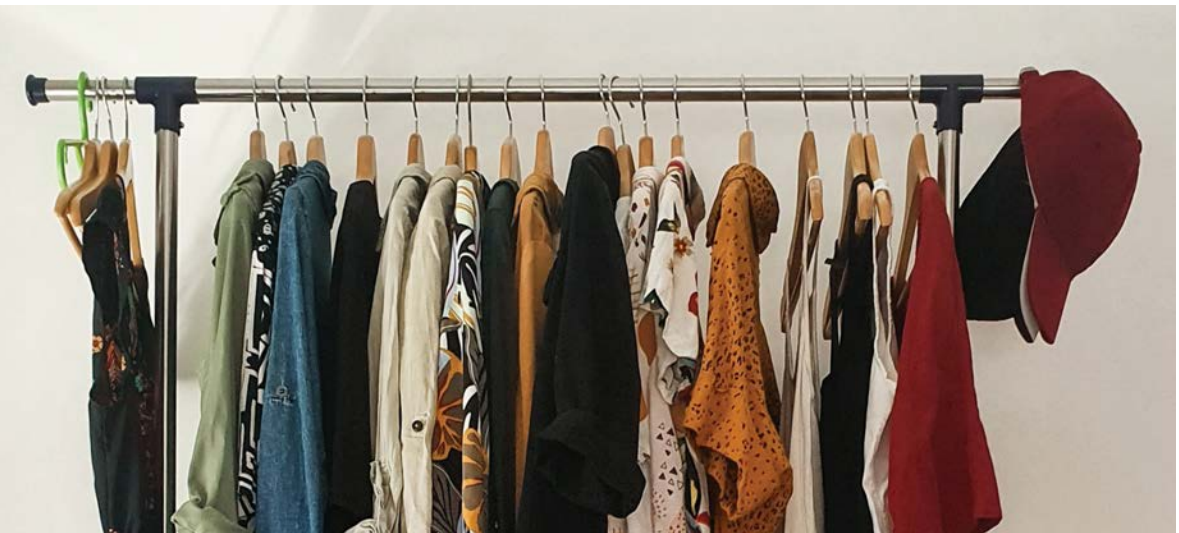
個案

3

FAIRBRICS



| | |
|--------------------|---------------------------------|
| FOUNDED 成立年份 | 2019 |
| HEADQUARTERS 總部 | Ile-de-France, France 法國法蘭西島 |
| FAIRBRICS.CO | |



French startup Fairbrics creates carbon-negative synthetic fibers from carbon dioxide waste, and has developed an alternative that is able to produce polyester with the least environmental impact. Taking greenhouse gas emissions from industrial fumes, Fairbrics converts carbon dioxide into polyester fabric using molecular chemistry. The captured carbon dioxide is reacted with a catalyst and solvent to generate chemicals used for polyester synthesis. After polymerization, polyester pellets are created and spun into yarn to make a sustainable polyester fabric. The captured carbon dioxide from industrial waste is notably ten times less expensive than petroleum, a core ingredient in the making of polyester-based fabrics. It is estimated Fairbrics has an impact of reducing 720,000 metric tons of carbon dioxide emissions by 2030, equivalent to reducing the emissions of 120 million polyester t-shirts.

法國初創公司 Fairbrics 成功從二氧化碳廢料合成出負碳排的纖維，更研發出生產聚酯纖維（Polyester）的替代方法，有效減低對環境的影響。Fairbrics 會從工業排放的煙霧提取溫室氣體，利用分子化學原理，與催化劑及溶劑產生反應之後，即產生用於合成聚酯的化學物質，再經過聚合讓聚酯顆粒精紡成紗線，並最終成為可持續的聚酯纖維紡織物。整個過程所利用的二氧化碳全來自工業廢料，其成本比聚酯纖維的主要成分石油便宜 10 倍之多。估計至 2030 年，Fairbrics 將有效減少 72 萬噸二氧化碳，相當於製造 1.2 億件聚酯纖維 T 恤的碳排放量。

Image Courtesy: Unsplash



Rubi Laboratories is a biotech company that turns carbon emissions into natural carbon-negative textiles through its cell-free enzymatic technology platform. Its textiles are akin to common fabrics used in the industry and are cost-competitive with the ability to scale for industrial production. Rubi's textiles are estimated to remove two regular bathtubs equivalent of carbon dioxide from the atmosphere. Its patent-pending technology grows and processes plant fibers into natural textiles without water, land, and chemically-intensive procedures. Where typically viscose is derived from wood pulp, largely contributing to deforestation, Rubi captures carbon dioxide from manufacturing waste streams and converts captured carbon dioxide into cellulose to create viscose-based yarn. By utilizing enzymes as the catalyst, 100% of carbon dioxide input is created into the end product with zero waste and is fully biodegradable.

生物技術公司 Rubi Laboratories 能以無細胞酵素技術，將碳排放轉化成天然的負碳排紡織品。這些紡織品與業內所用的一般布料非常接近，成本上亦具競爭力，因而極具用於大規模工業生產的潛力。據估計，Rubi 的紡織物料能從大氣去除相當於兩個普通浴缸的二氧化碳量，其正在申請專利的嶄新技術亦能在不耗水源、土地及密集化學流程下，將植物纖維轉化並製造成天然紡織品。作為常用的紡織原料，人造絲（Viscose）通常以木漿衍生，意味著會引致大規模砍伐森林，而 Rubi Laboratories 則選擇從製造業的廢物流中收集二氧化碳，然後利用酵素作為催化劑，將 100% 二氧化碳全轉化成纖維素（Cellulose），繼而製成可以完全生物降解的人造絲紗線，達至零浪費。

Image Courtesy: Rubi Laboratories



CASE STUDY

個案

2

RUBI LABORATORIES



| | |
|--------------------|-----------------------------|
| FOUNDED 成立年份 | 2020 |
| HEADQUARTERS 總部 | San Francisco, USA 美國三藩市 |
| RUBI.EARTH | |



LanzaTech specializes in renewable energy semiconductor manufacturing. By harnessing biology and big data, the company is able to convert waste carbon into usable fuel to create everyday items that would have otherwise come from virgin fossil resources. The platform converts greenhouse gases taken from industrial emissions, such as steel mills, and uses it as feedstock for microbes to turn pollution into fuels and chemicals. The bacteria converts carbon dioxide into ethanol, which is then used to supply manufacturing partners in creating other chemicals that would have normally been made from fossil fuels. LanzaTech leverages industrial emissions, whether gas or solid, to be reused, enabling a circular carbon economy and reducing overall carbon footprint. Applicable for many industries, so far its carbon-negative technology has proven to be scalable and has

supported the creation of innovative materials and everyday commodities.

專門製造可再生能源半導體的 LanzaTech，能巧妙運用生物學及大數據，有效將破廢料轉化成可用燃料，以製造本來靠原始石化資源生產的日常用品。平台會從鋼鐵廠等工廠生產的工業廢料中提取溫室氣體，作為微生物的能量原料，將污染物變成燃料及化學品。這些微生物會將二氧化碳轉化成乙醇，正好供應予工業合作夥伴去製造更多本來用石化燃料製成的化學品。LanzaTech 有效重新運用工業廢氣及固體廢料，成功實現碳經濟循環，並在整體上減少碳足跡。如此負碳排技術，不單適用於各行各業，更具有相當的擴展性，至今已支援多項創新物料及日用品的研發及生產過程。

Image Courtesy: lululemon



CASE STUDY

個案

4

LANZATECH



| | |
|--------------------|--------------------------|
| FOUNDED 成立年份 | 2005 |
| HEADQUARTERS 總部 | Illinois, USA 美國伊利諾伊州 |
| LANZATECH.COM | |

CASE STUDY

個案

5

ORIGIN
MATERIALS

FOUNDED
成立年份

2008

HEADQUARTERS
總部

California, USA
美國加州

ORIGINMATERIALS.COM

Origin Materials is a biochemical company that has developed a patented technology for converting carbon found in biomass into useful, everyday materials. Its unique and disruptive technology substitutes chemistry with biology, creating recyclable 100% plant-based PET plastic using carbon instead of fossil fuel oil. Predominantly using sustainable wood residue, alongside agri-waste and old cardboard, Origin Material's technology takes the sequestered carbon from the trees and plants as feedstock. In its process, it does not rely on expensive sugars or fermentation as it converts using chemical processes. Its end product is carbon-negative and can be applied to a wide range of end products, including clothing and textiles. Its PET products are chemically identical to those made from fossil fuels. Their solutions are cost-competitive with petroleum-based products and are recyclable, reducing the climate impact of products.

Origin Materials 已取得專利的獨有生化技術極具顛覆性，能將生物量中的碳轉變成日常物料，製造出 100% 植物性可回收 PET 塑膠，以取代石化燃料製品。平台主要使用可持續的木材殘渣、農業廢料及舊紙板等，提取被吸存於木質及植物中的碳作原料，再經由化學程序進行轉化。整個過程並不依靠成本高昂的糖或酵母，同時亦確保製成品的化學結構與一般化石燃料製的 PET 無異，大大提升成本競爭力，自然適用於更廣泛的日用品上，包括服飾及紡織品等。再加上負碳排，亦可以回收再利用，有效減少 PET 產品對氣候的影響。



Image Courtesy: Origin Materials

CASE STUDY

個案

6

NEWLIGHT
TECHNOLOGIES

∞ NEWLIGHT

FOUNDED
成立年份

2003

HEADQUARTERS
總部

California, USA
美國加州

NEWLIGHT.COM

生物技術公司 Newlight Technologies 能將溫室氣體轉化成可再生生物材料 AirCarbon，以取代石油製的聚酯塑膠物料，而且每合成生產 1 公斤物料，就會從大氣吸取 88 公斤二氧化碳。這間總部位於加州的初創公司，成功開發出獨特的生物技術，利用海洋中的微生物將溫室氣體轉化為負碳排物料。過程中，甲烷氣體及二氧化碳等污染物會作為飼料輸送給微生物，然後再將其排出的廢物乾燥成顆粒，經熔化再塑型後，就成為再生塑料。這些微生物所消耗的碳並不會重返大氣，製成品亦能完全生物降解，再配合使用區塊鏈，讓公司更有效追蹤、審計及展示產品的生產過程與對環境帶來的正面影響。



Image Courtesy: Newlight Technologies

Aside from using materials with low carbon impact, brands can also optimize their existing production processes to cut down on carbon emissions. Digitalization and biotechnology solutions have provided answers to reducing carbon emissions — whether it's using AI to trim down textile waste or by replacing harmful chemical processes with nature's own bacteria, the textile supply chain can be improved upon whilst benefiting the environment.

Image: Unsplash



GREEN MANUFACTURING:

OPTIMIZATION
OF PRODUCTION
PROCESSES

綠色製造：
改良生產過程

除了採用對碳排放較低的物料之外，各品牌亦可以改良其現有生產過程，以減少碳排放。數碼化及生物科技成功提供有效的解決方案，包括採用人工智能技術去減少紡織廢料，以及以天然存在的細菌代替有害的化學過程等，都可以改善紡織供應鏈，同時造福環境。



PRODUCTION PROCESSES

生產過程



An industry known to be greenhouse gas-intensive from unsustainable use of natural resources and excessive water waste, the primary source of pollutants in fashion predominantly lies in the make. The World Resources Institute states that 96% of a fashion brand’s footprint originates from the manufacturing stage. Throughout the supply chain, fiber production, yarn preparation, fabric dyeing, and finishing account for 15%, 28%, and 36% of carbon dioxide emissions respectively. Amongst these, the production of yarn and textiles holds the largest share of emissions, therefore developing cleaner production strategies, material and process innovation is imperative in reducing damage. Garment assembly and transportation bear lesser weight in emissions, though are still contributing factors.

Upon inspecting the life cycle of a garment, its impact on the environment and carbon footprint indicates problematic and high consumption areas that need to be fixed. Fortunately, digitalization and biotechnology solutions have provided answers to reducing carbon emissions — whether it’s using AI to trim down textile waste or by replacing

harmful chemical processes with nature’s own bacteria, the textile supply chain can be improved upon whilst benefiting the environment.

The implementation of blockchain is also beginning to be widely adopted within the industry to provide traceability and transparency across the supply chain, providing records to verify sustainable claims. Government legislation and industry regulations have also issued mandates to hold fashion houses accountable for their carbon emissions to pressure the larger players into sustainable supply chain commitments.

The root cause identified however is predominately attributed to textile companies and garment manufacturers reliance on fossil fuels and high energy consumption within its processes and production that largely contribute to fashion’s carbon footprint. These are mainly set off by cut-and-sew factories, dye houses, fabric mills, and farms. Given that many businesses do not own a vertical supply chain, these outputs are beyond their direct control, thus difficult to address.

The industry must work together on decarbonizing its supply chain to have a wider impact on the environment and achieve a low-carbon future. From farm to factories, brands and retailers, consumers and policymakers — all agents within the ecosystem are responsible for proactively limiting their carbon emissions.



眾所周知，時裝行業排放大量溫室氣體，耗損自然資源及過度浪費用水，難以保持可持續發展，而根本的污染來源主要就在製造過程中。世界資源研究所指出，每個時裝品牌有 96% 碳足跡在製造階段產生，而在整個供應鏈中，纖維生產、紗線製作、紡織物染色及後製，則分別佔二氧化碳排放量的 15%、28% 及 36%。由於生產紗線及紡織品的排放量佔最大比重，可見只要研發出潔淨的生產策略、物料及創新過程，就勢必能減少對環境造成的損害。而服飾縫合及運輸雖然在碳排放上，程度較為輕微，但仍會構成影響。

在檢視服飾的生命週期時，其對環境的影響，以及其碳足跡揭示出有問題及高消耗的部分，需要對症下藥去解決。幸而，數碼化及生物科技成功提供有效的解決方案，包括採用人工智能技術去減少紡織廢料，以及用天然存在的細菌去代替有害的化學過程等，都可以改善紡織供應鏈，同時造福環境。

區塊鏈亦開始被業內廣泛採用於提升整個供應鏈的可追溯性和透明度，同時提供記錄以驗證它的可持續性。另一方面，政府立法及行業法規制定時尚品牌對

其碳排放需要負上的法律責任，希望迫使業界內更大的持份者承諾走入可持續供應鏈的行列。

然而歸根究柢，時尚界碳足跡來自紡織公司及服飾製造商，他們過分依賴化石燃料，而且在製作流程及生產過程中的高度耗用能源。這類產業包括裁縫廠、染色廠、布料廠及農場，而基於大多數企業並未設有自家垂直供應鏈，讓他們無法直接控制此生產範疇，大大增加解決此問題的難度。

為此，業界必須共同努力協助供應鏈有效脫碳，從而對環境產生更廣泛的影響。無論是農場、工廠、品牌、零售商、消費者以至政策制定者，大家作為生態系統中的一份子，都有責任主動限制碳排放，真正實現低碳未來。

UNSPUN: SUSTAINABLE 3D-SCANNING JEANS

UNSPUN: 可持續 3D 掃描牛仔褲

One of the most polluting products in the world is a pair of denim jeans – which has one of the most devastating impacts on the environment. From cotton production to its end-of-life, the standard manufacturing process needs to be redesigned to clean up denim’s dirty reputation. It takes an average of 10,000 liters of water to produce one kilogram of cotton fabric, from the growing of cotton to garment making. Apart from cotton’s high water need, high amounts of high amounts of pesticides are also used, which have adverse health effects if humans are exposed to it. The mechanical processes of spinning and weaving denim is also energy intensive. Aside from water pollution, harmful chemicals are also present in the bleaching, sandblasting and dyeing stages polluting. Furthermore, the synthetic elastane used to create stretchiness in jeans is difficult to break down and releases toxic fumes if it’s incinerated at the end of its product life cycle.

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| UNSPUN | FOUNDED 成立年份 | 2015 |
| | HEADQUARTERS 總部 | California, USA 美國加州 |
| UNSPUN.IO | | |

What’s more, poor construction of denim leading to ill-fitting jeans has built up excessive inventory. This is where techstyle brand Unspun steps in, transforming the jeans industry with an on-demand made-to-order model. With the aid of robotics, the company creates bespoke jeans for each consumer, tackling the industry’s waste problem by eliminating surplus inventory, excess fabric and ill-fitting jeans. The company aims to reduce global carbon emissions by 1% through its automated and localized manufacturing system.

世上帶來最大污染、並對環境影響最大的其中一種產品是牛仔褲。從生產棉花開始，一直到牛仔褲被丟棄，其標準生產流程非常需要重新設計以消除牛仔褲的污名。平均來說，要得到 1 公斤棉布料就需要運用一萬公升水去種植及採摘所需要的棉花，連帶噴灑有機會危害生命的殺蟲劑用量，並需要在紡織牛仔布的機械過程中動用大量能源。除了污染水源之外，漂白、噴砂及染色過程亦會帶來有害化學物質，最終成為重金屬污染河流。而為了增加布料彈力而添加的合成彈性纖維，不單難以分解，更會在被焚毀時釋放有毒氣體。

牛仔褲只要剪裁設計不當，這些不合身的牛仔褲定必銷情慘重，導致廠商囤積存貨。這正是紡織科技品牌 Unspun 所針對的範疇，希望透過按需求訂造的模式，改變牛仔褲行業。在機械人技術的協助下，品牌會為每位消費者度身訂造牛仔褲，有效消除過剩存貨、多餘布料及不合身的產品，一次過解決所有浪費問題。品牌期望透過自動化及本地化生產系統，減少 1% 全球碳排放量。

UNSPUN

Image Courtesy: Unspun



“FROM FARM TO FACTORIES, BRANDS AND RETAILERS, CONSUMERS AND POLICYMAKERS — ALL AGENTS WITHIN THE ECOSYSTEM ARE RESPONSIBLE FOR PROACTIVELY LIMITING THEIR CARBON EMISSIONS.”

「無論是農場、工廠、品牌、零售商、消費者以至政策制定者，大家作為生態系統中的一份子，都有責任主動限制碳排放，真正實現低碳未來。」



Where typically polyester and elastane are used in creating the stretch, Unspun uses biodegradable lycra, roica or eco-lycra and has completely phased out on all use of virgin polyester. More than 98% of its material components are cellulose-based where even its stitching threads are dissolvable, as supplied by Belgian startup Resortec. Its buttons are made from non-electroplated raw zinc alloy, easily removable for recycling or reuse, zippers from non-electroplated brass, and its zip tape from post-consumer recycled polyester. Sending jeans back to Unspun to be dissembled can also reduce carbon impact by 70%.

To order a pair of Unspun jeans, customers can visit its retail store or pop-up to get measured by its 3D body scanner. At the pandemic, in-store operations halted. Unspun has accelerated its business' digital transformation plan and developed its own technology to operate within an iPhone. So that consumers can conduct their own scanning at home. Currently in beta mode, the smart device projects over 300,000 dots of infrared light on the body. As the consumer rotates, the sensor stitches all depth maps together to create a hyper-accurate 3D model body.

Unspun 嚴選所採用的物料，有超過 98% 以纖維素作為基礎。而一般品牌使用聚酯及彈性纖維去製造彈力，Unspun 則選用可生物降解的 Lycra、Roica 或環保 Lycra，以完全取代所有原聚酯纖維，縫合線則由比利時初創公司 Resortec 供應的可溶解縫線；褲上的鈕扣由非電鍍生鋅合金製成，易於拆下作回收或重複使用；拉鍊由非電鍍黃銅製成，而拉鍊帶則由消費後回收的聚酯製成。需要丟棄的牛仔褲更可被送回 Unspun 分拆，藉此減少 70% 碳排放量。

想要訂製 Unspun 牛仔褲的話，顧客會被邀請至其零售店或快閃店，經 3D 人體掃描器度身。但在疫情肆虐之下，實體商店不得已暫停營運，卻因此推動了企業的數碼化轉型計劃，成功將技術應用到 iPhone，好讓顧客能在家中自行掃描。技術目前處於測試階段，能透過智能裝備在身體上投射超過 300,000 個紅外線光點，並隨著顧客自轉，感應器將拼接起所有深度圖，輕易建立極度精確的 3D 軀體模型。

他們除了採購及利用低環境影響的布料，更透過人工智能及 3D 技術而研發的自家度身訂造流程達致大大減少紡織廢料。它們並成功開發 3D 掃描及編織機，能一條龍從紗線直接編織產品，省去傳統編織步驟，從而解決廢棄紡織物的浪費問題。

與快時尚的速度與成本相比，要成功將訂造時裝引入主流市場顯然充滿挑戰。然而，Unspun 有望能透過可被業界廣泛採用的高利潤訂造模式，成功解決此一大障礙。當中，就採用數碼化應對客製流程上，Unspun 就成功做到經濟上可行、同時環保的營運模式。品牌更將其技術外判予第三方品牌，例如 H&M 旗下的 Weekday 及可持續品牌 PANGAIA，好讓他們的顧客能在兩至三星期內設計出最適合自己身型的牛仔褲。

Unspun's on-demand process dramatically reduces waste through its AI and 3D technology, in addition to sourcing and crafting from low-impact fabrics. The techstyle startup developed a 3D scanning and weaving machine where the garment is woven straight from yarn to product, skipping traditional weaving steps and getting rid of scrap fabric wastage.

Bringing bespoke clothing to the mainstream market is a challenge when competing with the speed and cost of fast fashion. However, Unspun believe they have tackled the obstacle with a highly profitable, made-to-order model that can be widely adopted by the industry. In digitalizing on-demand manufacturing, Unspun has developed an economically viable model that is also environmentally impactful for the industry. The company also outsources its technology to third-party brands such as **H&M's** Weekday and sustainable brand **PANGAIA**, enabling their audience to design their own custom-fit jeans that can be delivered to them within two to three weeks.

“UNSPUN'S ON-DEMAND PROCESS DRAMATICALLY REDUCES WASTE THROUGH ITS AI AND 3D TECHNOLOGY, IN ADDITION TO SOURCING AND CRAFTING FROM LOW-IMPACT FABRICS.”

「他們除了採購及利用低環境影響的布料，更透過人工智能及 3D 技術而研發的自家度身訂造流程達致大大減少紡織廢料。」



CIRC: BREAKING DOWN OLD FABRICS INTO NEW FIBERS

CIRC: 讓舊織物分解成新纖維

CIRC



FOUNDED
成立年份

2011

HEADQUARTERS
總部

Virginia, USA
美國維珍尼亞

CIRC.EARTH



The creation of fabrics have a detrimental effect on landfills, water consumption, and chemical pollution. The demand for more natural raw materials like cellulosic fibers may lead to deforestation and recycled fabrics are not entirely sustainable. Garments at their end-of-life either clog landfills or intoxicate the planet with more greenhouse gas emissions when burned. And when it comes to recycling textiles, even though other companies can dissolve most materials, traces of polymers are preserved, and the quality of cotton fibers are degraded to the point of being unsalvageable.

Powered by renewable energy and resources, Circ combines water, pressure, heat, and chemicals to break down and purify textile fibers, and in the process to get rid of toxins and microfibers. The process can recover up to 90% of the material's original state. The technology can be applied to a broad spectrum of materials such as cotton, polyester, and polycotton without compromising on quality, at a cost equal to that of new materials.

Circ is a pioneer in the field of apparel recycling turning old clothes, through hydrothermal processes, to new raw materials. This eliminates the need for raw ingredients and enables creating new clothes out of old ones, with a material quality that's comparable to fabrics derived from virgin materials.

By designing this closed-loop system, its solution prompts manufacturers to purchase circular fibers in place of virgin materials, in doing so helping to curb carbon footprint. The startup aims to help recycle 10 billion garments, representing 10% of the global apparel market, and to save more than 10 million trees by 2030.

紡織品的出現，對垃圾堆填區、用水量及化學污染等帶來不良影響，同時，原材料供過於求、為取得纖維素纖維而砍伐森林、以至回收紡織物等，亦非全然屬可持續發展。被丟棄的服飾要麼被堵塞於垃圾堆填區中，要麼就在被燃燒時排出更多的溫室氣體，毒害整個地球；而回收紡織品時，縱使大多數質料都能被溶解，惟聚合物的痕跡依然存在，棉纖維的質素亦低劣至無可回收的程度。

Circ 利用可再生能源及資源作動力，結合水、壓力、熱力及化學物，能有效分解及淨化紡織纖維，同時去除過程中釋放的毒物及微纖維，可將多達 90% 的衣物還原成原始狀態。此技術可應用於棉、聚酯纖維及混紡棉等多種物料上，並能保持品質，成本亦與生產全新物料相約。

作為循環再生紡織物品的先驅，Circ 透過水熱技術，從衣物廢料搜集及收取原材料，好讓衣物能夠還原成原材料狀態。此技術完全消除行業對原材料的需求，反其道而行，使用老舊或可回收的纖維製作衣服，並確保當中纖維與全新原材料無異。

設計這個閉環系統是希望推動製造商購買循環纖維，以取代原始布料，並減少碳足跡。而 Circ 的目標是在 2030 年或之前成功協助回收一百億件衣物，佔全球服飾市場 10%，但足以拯救超過一千萬棵樹木。

CIRC



Image Courtesy: Circ Facebook

COLORIFIX:
DYED FROM
NATURE’S DNA

COLORIFIX:
以大自然中的 DNA 染色

From natural pigments to industrial age dyes, the dyeing sector has evolved to become the most toxic and polluting step in addition to leaving the largest water footprint. Conventional dyeing is composed of high doses of harsh chemicals, such as arsenic metals and salts to create a permanent bond between color and fiber. Up to 200,000 tons of dye are lost to effluents every year, bleeding into rivers and polluting drinking water for many in a region.

Colorifix is a biotech company that revolutionizes the dyeing process through synthetic biology using microorganisms to grow and transfer color onto textiles. Harnessing the ability of microbes, they can create non-polluting dyes that provide the same vibrant outcome as commercial dyes and are non-toxic, hypoallergenic, and free from any hazardous chemicals. By replacing chemistry with biological processes, a cleaner input and output in dyeing have been achieved while minimizing environmental impact.

The laboratory first identifies DNA codes from naturally occurring pigments — in animals, plants,

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| COLORIFIX | |
| FOUNDED 成立年份 | 2016 |
| HEADQUARTERS 總部 | Norwich, United Kingdom 英國諾域治 |
| COLORIFIX.COM | |

or insects – to pinpoint and copy the exact genetic code of the pigment before transferring into a microbe. The bacteria replicate the DNA code of the color found in nature and splits itself every 20 minutes to produce a pigmented color and copious amounts of dye liquor. The dyes are grown on-site at dyehouses with renewable feedstock (sugar, yeast and plant byproducts) to continue growing color through fermentation. Colorifix can send as few as 50ml of color-packed bacteria to the dyehouse which will multiply itself in ten days, producing up to 50 tons of dye solution a day. The output can be placed directly into standard dye machines (e.g. jet machine), requiring only a low-cost, bespoke fermenter that can easily plug into the existing infrastructure of dyehouses. This semi-distributed model reduces carbon dioxide emissions associated with the current supply chain of 20-tonne tankers typically used to transport synthetic dyes to dyehouses around the world. However, each mill must apply for a biological license before they can handle the microorganisms on-site, an onboarding process the Colorifix team of specialists will aid with.

Colorifix’s solution has proven to be non-toxic and cost-competitive, on par with synthetic dyes while meeting industry standards. The bacteria-produced dyeing procedure uses 49% less water and 39% less energy in comparison to using petrochemicals. Colorifix has reduced at least 31% of carbon emissions at every step in the dyeing process. So far, the biotech company has worked with brands and manufacturers that resonate with its sustainability values and incorporated its revolutionary dyeing technique into their manufacturing stages. From partnering with retail giants such as **H&M** to sustainable indie brand **Pangaia**, Colorifix has successfully proven its colorfastness without compromising on quality and is more kind to the/better for the environment. Although its cost currently sits at 20% more than conventional processes, the start-up is actively decreasing the price gap.

COLORIFIX

從天然顏料至工業時代的染料，染色業一直都製造最多污水，更發展成最具毒性及帶來最大污染的行業。傳統染色由高劑量的刺激性化學物質組成，例如砷金屬加鹽，以求將顏色及纖維永久黏合，但此類染料每年卻有多達 200,000 噸持續經污水排放，繼而流入河流，並污染當地飲用水。

Colorifix 作為生物技術公司，成功透過合成生物學，有效利用微生物生長顏色，再轉移到紡織品上，徹底改變染色程序。全靠微生物獨特的能力，製成的無污染染料不單無毒、低過敏性、不含任何有害化學物質，更能呈現與商業染料同樣的鮮豔效果。這樣以生物代替化學流程，讓染色前期用料至後期廢料皆更潔淨，最大程度減低對環境的影響。

品牌的實驗室一開始由來自動物、植物或昆蟲等的天然色素中識別基因碼，經準確指出並複製完全相同的基因碼後，再轉移至微生物上。微生物會複製自然色彩的基因碼，並每 20 分鐘自行分裂一次，從而產生已著色的色澤及大量的

染色液。這些染料能在染色廠中經可再生原料（包括糖、酵母及植物副產品）進行發酵培植，持續生長出顏料。而 Colorifix 就可以提供少至 50 毫升連顏色的細菌送到染色廠，讓染色廠自行在 10 天內生產每日多達約 50 噸的染色液。要將這些染料直接應用於標準染色機器（例如噴射染色機）上，只需要一個便宜的訂造發酵罐，即可輕易插入染色廠本身的基礎設施中。相比起以往要用 20 噸運油輪將合成染料運輸到世界各地，如此半分布操作模式，就有效減低供應鏈的二氧化碳排放。然而，工廠必須事先申請生物許可證，才能在廠房處理微生物，為此，Colorifix 的專家團隊會在啟用過程中提供全面協助。

Colorifix 的解決方案已被證實為無毒，且具成本競爭力，效果媲美合成染料之餘，亦符合業界標準。與此同時，利用細菌推動的染色過程會比使用石化產品耗用少 49% 水源及 39% 能源，而每個染色步驟亦至少減省 31% 的碳排放量，用於聚酯纖維或尼龍等紡織品上的話，估計減排量更高！時至今日，多間同樣抱持可持續理念的品牌及製造商與 Colorifix 合作，將品牌革命性的染色技術應用於生產階段。而能與 **H&M** 一

類大眾品牌以及可持續發展的獨立品牌 **Pangaia** 等合作，亦足證 Colorifix 能兼顧色牢度（colorfastness）及品質，同時對環境友善。儘管其成本目前依然比傳統技術高出 20%，但品牌正積極減小價格差距，進一步提升其競爭力。

Image Courtesy: Colorifix



AIR PROTEIN:
CONVERTING CARBON DIOXIDE
INTO JUICY MEAT

AIR PROTEIN:
讓二氧化碳轉化成滋味肉食

By 2050, the world will need to feed 10 billion people, requiring food resources to increase by 56%. The food system already represents one-third of global greenhouse-gas emissions with livestock production being one of the top contributors to greenhouse-gas emission, at 7.1 gigatonnes annually. Worryingly, global emission is expected to rise by 60% by 2050.

Unlike other alternative meat companies, Air Protein has created a sustainable protein made from elements in the air without compromising on taste, nutrition, and the climate. Inspired by NASA’s culinary fermentation technique, AirProtein has

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| AIR PROTEIN | |
| FOUNDED 成立年份 | 2019 |
| HEADQUARTERS 總部 | California, USA 美國加州 |
| AIRPROTEIN.COM | |

manufactured a meat alternative from air that can be farmed at any climate, geography, and any time of day — resulting in a new protein being made within a few short hours. The result is a nutritious, mineral and vitamin-rich meat with more protein per kilogram than regular meat — yet does not emit as much greenhouse gas and only requires minimal resources and land.

By using elements of the air — carbon dioxide, nitrogen — whisked together with their cultures, proteins are produced in a process powered by renewable energy. The protein in the cultures are then harvested, purified, and dried to remove water,

resulting in a protein-packed flour that is ready to be made into any meat. Culinary techniques are further applied to the flour to recreate the texture and flavor that is akin to animal protein. This carbon-negative product is naturally low in emissions as it only uses 0.8 liters of water per kg of protein — versus the 15,000 liters per kilo of beef usually needed.

AIR PROTEIN



至 2050 年，全球人口將達 100 億人，並因此需要增加 56% 的糧食資源。然而，養殖肉食是主要貢獻溫室氣體的行業之一，每年排放 71 億噸溫室氣體。其實，糧食生產早已是佔全球三分之一的溫室氣體排放，並將預計於 2050 年隨著牲畜產量增加而進一步增長 60%，情況令人擔憂。

近年不斷出現的替代肉食中，Air Protein 的獨特之處在於它以空氣中元素創造出可持續蛋白質，而無損味道、營養及氣候。受美國國家航空航天局的發酵烹調技術所啟發，Air Protein 成功研發源自於空氣的肉類代替品，只需短短幾個小時，就能隨時隨地、以至任何氣候下培植出新型蛋白質。製成品營養豐富、飽含礦物質及維他命，每公斤所含的蛋白質更比天然肉類要多，卻同時不會排放太多溫室氣體，且只耗用相當少的資源及土地。

空氣中所含的二氧化碳、氮氣，再加一點點可再生能源及培養物，經攪拌後就會成為蛋白質豐富的成分。當中的蛋白質再經收取、純化及去除水分後，就能生產富含蛋白質的麵粉，以製成各種「肉類」。配合更獨特的烹調技術，麵粉會被進一步重現類似動物蛋白的質感和風味。達負碳級別的製成品，碳排放量低之餘，生產每公斤蛋白質更只需要使用 0.8 升水，與正常生產每公斤牛肉要用 15,000 升水相比，大大節省耗水量。

Image Courtesy: Air Protein



THE MILLS FABRICA SPEAKS TO... DR. SHAUHRAT CHOPRA

南豐作坊對談：
SHAUHRAT CHOPRA 博士

Image Courtesy: Unsplash



DR. SHAUHRAT CHOPRA

Assistant Professor at
the City University of Hong Kong

To build a low-carbon pathway for the fashion industry, Life Cycle Assessment (LCA) can be conducted to analyze the entire environmental impact associated with a product, from cradle to grave. This includes all stages of a garment's life cycle, beginning with raw material extraction, textile production, manufacturing, retail distribution, usage, and disposal. The results can be used to critically reflect on the resources required to produce a garment and other associated outputs including material wastage and carbon dioxide emissions.

To learn more about this methodology, The Mills Fabrica spoke to expert Dr. Shauhrat Chopra, an Assistant Professor at the City University of Hong Kong. His research revolves around building a socially just and sustainable future that is both environmentally and economically feasible. Shauhrat's

1. WHAT IS A LIFE CYCLE ASSESSMENT AND WHAT IS THE PURPOSE OF ONE?

Life Cycle Assessment (LCA) is a tool for the systematic accounting of environmental impacts across the life cycle of a product or a process. LCA can be conducted for two purposes: first, to benchmark the environmental performance of a product or process to identify opportunities for a sustainable design, and second, to compare two alternative pathways to achieve the same functionality. Systematic comparative assessments that are not based on intuition are necessary to avoid unintended consequences.

LIFE CYCLE ASSESSMENT



research is focused on designing indicators to support data-driven environmental decision-making, such as enhancing the sustainability and resilience of the built environment.

Prior to City University, Shauhrat was working as a post-doctoral associate at the Institute of Environmental Science and Policy, University of Illinois at Chicago and received his Ph.D. in Civil and Environmental Engineering from the University of Pittsburgh.

在為時裝界構建低碳之路的過程中，大家有機會採用到生命週期評估（LCA）去分析和評估產品從設計到被銷毀，整個過程的每個程序對環境帶來的影響。整個評估需囊括衣飾所有生命週期中的階段，包括提取原材料、生產紡織品、製造、零售分銷、使用及丟棄，結果反映出需耗用的資源、造成的浪費、還有二氧化碳排放。

為了進一步了解這方法，南豐作坊特別採訪了香港城市大學的助理教授 Shauhrat Chopra 博士。Shauhrat 著眼於建立一個環境及經濟上皆可行，同時保持社會公正性及可持續發展的未來，藉著這個以數據為本的研究，制定建築環境的可持續性和復原力指標，協助支持環境決策。

在加入城市大學之前，Shauhrat 曾在芝加哥伊利諾伊大學環境科學與政策研究所擔任博士後研究員，並取得匹茲堡大學土木與環境工程專業頒授的博士學位。

2. HOW CAN A TEXTILE MANUFACTURER OR FASHION RETAILER UNDERTAKE ITS OWN LCA TO OPTIMIZE ITS PRODUCTION PROCESSES?

LCA is an ISO standardized methodology, which is widely adopted across sectors. Lately, textile manufacturers and retailers have been pushed by consumers' outcry against the environmental burden of fast fashion. As a response, many brands have launched sustainability initiatives; however, the concern of greenwashing remains. For this reason, it is essential to perform LCAs to benchmark impacts for much greater transparency.

The four stages of LCA are:

- 1) goal and scope definition, where we define the objective and the system boundary;
- 2) Life Cycle Inventory (LCI), where we collect all the material and energy inputs, and waste and pollutants outputs from each of the life cycle phases;
- 3) Life cycle impact assessment converts the input and outputs into environmental impact categories;
- 4) Finally, an interpretation phase where analyzing the detailed breakdown of the sub-processes that contribute the most environmental impacts and perform scenario analysis to evaluate the alternatives.

Life Cycle inventory data is mostly obtained from industry average datasets, such as Ecoinvent. However, these databases do not contain data for the latest emerging technologies and most of the data is representative only of the Global North.

1. 何謂是生命週期評估（LCA）？其目的是甚麼？

生命週期評估（LCA）是一種工具，用於有系統地計算產品或流程的整個生命週期中帶來的環境影響。LCA 可用於兩大目的：一是對產品或流程的環境性能進行基準測試，以確定其可持續的設計潛力；二是對比兩種能實踐相同功能的替代方案，而這種系統化的比較評估，不建基於直覺，有效避免出乎意料的後果。

2. 紡織品製造商或時裝零售商如何進行 LCA，以改良其生產流程？

LCA 作為 ISO 標準化方法，在各行各業中已被廣泛採用。最近，消費者針對速食時尚為環境帶來的負擔提出強烈抗議，紡織品製造商和零售商為作出回應，不少品牌都陸續推出可持續發展計劃。然而，業界相當關注「漂綠（greenwashing）」的可能性，因此就確切執行 LCA 來衡量影響，以提升透明度。

LCA 分四個階段：

- 1) 目的與範圍定義，用於定義評估目標及系統界線；
- 2) 生命週期盤點（LCI），用以收集所有物料及能源輸入，以及生命週期各階段的廢物與污染物輸出；
- 3) 生命週期影響評估會將輸入和輸出轉換為各種對環境影響的類別；
- 4) 最後的闡釋階段，會詳細拆解及分析對環境影響最大的中間流程，並進行情景分析，以評定可作替代的方法。

當中，生命週期盤點的數據主要來自行業平均數據集，例如 Ecoinvent。然而，此類數據庫並不包含最新的新興技術數據，且大部分數據只代表歐美及已發展亞洲國家。

3. WHAT IS THE DIFFERENCE BETWEEN CALCULATING CARBON FOOTPRINT AND LCA? HOW CAN THE TWO METHODOLOGIES BE INTEGRATED FOR ONE TO CUT DOWN ON CARBON EMISSIONS?

LCA is not restricted to just the quantification of carbon emissions, which means it is able to disclose the trade-offs between various environmental impacts, such as land-use change, ozone depletion, and human health toxicity, to name a few among others. This makes carbon footprint a sub-set of LCA.

Given that textile products are associated with water depletion and land-use change issues, it will be silly to optimize the production processes with the only aim to reduce carbon alone. It is imperative to drive sustainable design towards balancing all the different environmental impacts.

4. AFTER EVALUATION, HOW CAN THE LCA ASSESSMENT BE USED TO SUPPORT ONE'S SUSTAINABILITY GOALS AND STRATEGY? HOW CAN BUSINESSES GET THE MOST OUT OF THEIR LCA RESULTS?

LCA allows for data-informed decision-making for various stakeholders engaged in the value chain of the textile product. For instance, by looking at the end-of-life impacts associated with a garment, fashion designers can fine-tune their material selection and inculcate design-for-circularity in the early phases of the garment life cycle.

5. HOW SUSTAINABLE IS IT TO USE BIOLOGICAL METHODS TO RECYCLE GARMENTS?

Biological approaches are a promising technology for textile waste valorization to different chemicals. While biological recycling method is still quite nascent, it is promising to see the latest development in treating cotton-polyester blended waste streams to produce platform chemicals such as glucose and polyester.

6. EMERGING BIO-TECH START-UPS FACE THE CHALLENGE OF SCALING THEIR PROCESSES FOR COMMERCIAL PRODUCTION. HOW CAN THESE COMPANIES IMPROVE IN SUSTAINABILITY AND COST-EFFECTIVENESS?

While previously engineers mostly cared about the technical performance (i.e. yield) or the financial viability of the technology, there is a need to scale emerging bio recycling of textile waste streams whilst keeping economic and environmental sustainability variables in mind. Techno-economic analysis, also known as life cycle costing, and LCA allow us to identify the scenarios that strike a balance between economic costs and environmental benefits. Previous studies have pointed to the high environmental and financial cost of enzymes, which makes it the major hotspot for intervention.

3. 計算碳足跡和 LCA 有何差別？如何整合這兩種方法以減少碳排放？

LCA 不僅限於量化碳排放，更能夠揭示各種環境影響之間的權衡抵消，例如土地利用變化、臭氧消耗、對人體的毒性等等，而碳足跡則只是 LCA 的其中一個分支。

紡織產品與水資源枯竭及土地利用變化問題息息相關，僅以減碳排作目標去改變生產過程其實只是自欺欺人，業界必須推動可持續設計，以平衡各種環境影響。

4. 評估之後，應如何使用 LCA 評定去支持某個可持續發展目標和策略？企業應怎樣充分利用他們的 LCA 結果？

LCA 讓紡織品價值鏈中的各方持份者基於數據進行決策，例如透過了解丟棄衣物所帶來的影響，時裝設計師就可以調節他們所選擇的用料，並在服裝生命週期的初段就注入循環設計的理念。

5. 使用生物性的方式回收衣物有多大可持續性？

生物取向方法能將紡織廢料轉化為不同的化學品，是非常具有前景的技術。雖然生物回收方法仍處於初發展階段，但仍期望看到利用棉聚酯混紡纖維廢物流（cotton-polyester blended waste streams）去生產葡萄糖及聚酯等平台化合物的最新發展。

6. 新興的生物技術初創企業一直面臨擴充流程以應付商業化生產的挑戰，你會建議他們如何提升可持續性與成本效益？

工程師以前主要只關注技術性能（即產量）或技術的財政可行性，但如今更加有需要擴大新興的生物回收紡織廢料流，並同時緊記兼顧經濟及環境的可持續性。技術經濟分析（亦即為生命週期成本計算）與 LCA 正讓我們能保證在經濟成本和環境效益之間取得平衡。過去已有研究指出酶擁有高環境及財政成本，而這代表着未來可改善的主要熱點。



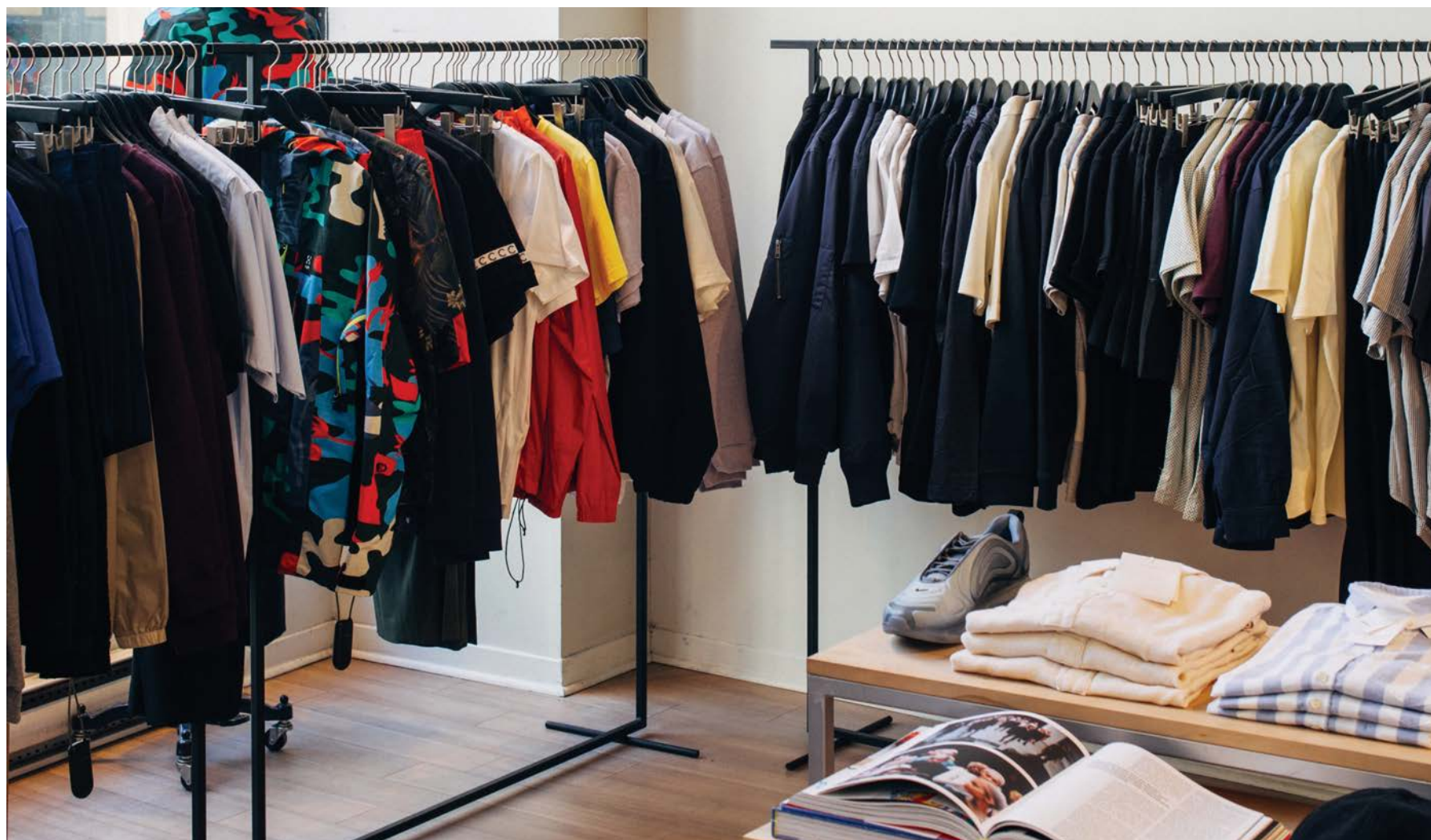
CARBON INSETTING:

THE 'INSIDE OUT' APPROACH

碳回饋： 從內到外的新趨勢

90% of a company's climate impact originates from its supply chain. However, many businesses do not operate their own production facilities therefore they often outsource their production. This means they have limited control or knowledge of the emissions produced within their entire supply chain.

一間公司為氣候帶來的影響中，有 90% 其實來自其供應鏈，然而，許多企業因為未有營運自家生產設施，需要四出採購產品，自然難以控制或了解其供應鏈所產生的碳排放程度。



“INSETTING TAKES PLACE BY WORKING WITH VARIOUS STAKEHOLDERS WITHIN THE VALUE CHAIN TO IDENTIFY EMISSION REDUCTION OPPORTUNITIES, RATHER THAN TAKING A REACTIVE STANCE POST-POLLUTION THROUGH FINANCIAL MEANS.”

Other than using alternative materials or modifying manufacturing processes, a new and innovative approach to carbon footprint reduction is called carbon insetting which focuses on reducing GHG emissions directly from the source and monitoring the overall supply chain management for other emission reduction opportunities.

Not to confuse insetting with offsetting, the latter consists in paying off carbon emissions from elsewhere as a contribution to mitigating the climate crisis, and is a practice that many companies have adopted to continue polluting without actually lowering their own carbon footprint. Carbon offsetting should not be used as a method to buy a way out of the issue of unavoidable greenhouse gas emissions. In fact, carbon offsetting can be seen as merely a financial transaction between the purchaser and the offset provider.

Insetting, on the other hand, takes place by working with various stakeholders within the value chain to identify emission reduction opportunities, rather than taking a reactive stance post-pollution through financial means. This concept fosters more than just a collaborative carbon footprint reduction, as it encourages stakeholders to build a more resilient supply chain that is more sustainable and provides greater benefits for the surrounding communities.

For example, within the fashion industry, the majority of emissions lie with the indirect GHG emissions from upstream activities such as the sourcing and cultivation of raw materials. Since they are usually outsourced it means brands are not in control of their indirect emissions and becomes problematic when trying to setup carbon insetting programs. Instead, the focus should shift

towards prioritizing the reduction of greenhouse gas emission in the manufacturing stage. For example, this includes creating carbon storage capabilities and utilizing more green energy. For companies, this is a long-term strategic investment designed to achieve their sustainability goals but also it represents an investment in creating permanent sustainable practices within its supply chain, whilst also creating long term positive impact for communities and the wider ecosystem.

As carbon insetting is still a relatively young concept, there are no official certifications and can only be verified by independent auditors. To begin a carbon insetting project, screening of the supply chain should take place to identify carbon emissions hotspots and it's often at one's source of energy. After mapping out areas for improvement, businesses should collaborate with stakeholders through knowledge sharing and developing projects targeted to reduce emissions. This may include conservation through agroforestry and regenerative agriculture practices, which in the long run will build supply chain resilience for the business while improving the quality of raw materials and keeping future costs of carbon abatement low.

Carbon insetting will become an embedded practice to actively decarbonize the supply chain. Businesses that embrace carbon insetting will win as an environmental leader and create long-term competitive advantages in improving their supply chain efficiencies. More than just a transactional relationship, carbon insetting activities factors the whole ecosystem and local communities – from farmers to customers, and will help build trust and project greater transparency in supply chain activities for a carbon-free future.

「回饋則從另一方面入手，透過與價值鏈中各個持份者合作，共同實現減少碳排放的可能，而非在污染出現之後才付出金錢作回應姿態。」

除了改用替代物料或改良製造技術之外，最近業界間亦興起一種減少碳足跡的創新方法，就是直接從源頭改變，專注於監控及管理整體供應鏈，以作更長遠計劃。就時尚領域來說，在此之前，讓我們釐清回饋（Insetting）與補償（Offsetting）的分別。後者是不少公司因應氣候危機而採取的行動，就是在一邊抵消碳排放，卻在另一邊繼續污染，意味著未有實際減低其碳足跡。這樣的碳補償其實並不應當能抵消或取代無可避免地排放溫室氣體的方法，因為兩者之間並無直接關係，充其量只能視為消費者和補償提供者之間的經濟交易。

而回饋則從另一方面入手，透過與價值鏈中各個持份者合作，共同實現減少碳排放的可能，而非在污染出現之後才付出金錢作回應姿態。這種概念不僅能實際促成減低碳足跡的合作，更能鼓勵生態系統中的持份者一同採取實質行動，共同建立一個可持續發展、並有利於社區的堅韌供應鏈。

就時尚領域來說在，大部分排放來自上游活動的間接溫室氣體排放，例如在採購原材料階段。由於大部分的品牌都需要外判生產工序便更加難控制其排放量，自然無法做到碳回饋。重點應轉向優先減少製造階段排放的溫室氣體，譬如提升碳儲存能力或利用多些綠色能源。對於公司而言，此舉不單被視為實現可持續發展目標的長期策略投資，同時亦可為供應鏈內的可持續方案投放資源，無疑顧及到廣大社會及環境影響下的未來。

由於碳回饋仍是個較新興的概念，且尚未有官方認證，因此只能靠獨立審計師進行驗證。在開展碳回饋項目前，公司需要先篩選供應鏈中的合作單位，以確認其碳足跡及消耗能源的主要熱點。之後，企業制訂好需要改善的範圍，就可透過分享知識與各持份者合作，甚至一起策劃有助減少碳排放的活動，包括參與混農作業（Agroforestry）及再生農耕（Regenerative Agriculture）等保育項目，長遠為業務建立供應鏈韌性，同時提升原材料質素，並減低將來需要承擔的減碳排成本。

碳回饋作為一種嵌入式方案，能積極帶領供應鏈脫碳；而支持碳回饋的企業，更將贏得環保上的領導地位，兼提升供應鏈各方面的效率，達成長遠的競爭優勢。碳回饋活動並非止步於一場交易關係，更放眼於整個生態系統與當地社區，從農民及至客戶，有助建立供應鏈間的信任度並提升透明度，實現無碳未來。

PRODUCING CARBON COMPENSATE CLOTHING

製造碳補償服飾

GANNI

FOUNDED 2000
成立年份

HEADQUARTERS Copenhagen, Denmark
總部 丹麥哥本哈根

GANNI.COM/EN/HOME

GANNI

Image Courtesy: Ramil Factory



CARBON NEUTRAL COFFEE CAPSULE INDUSTRY

碳中和咖啡膠囊產業

NESPRESSO

FOUNDED 1986
成立年份

HEADQUARTERS Lausanne, Switzerland
總部 瑞士洛桑

NESPRESSO.COM

NESPRESSO

Image Courtesy: Nespresso



Since 2016, Denmark-based fashion brand **Ganni** has been mapping out the carbon footprint of its entire value chain. Yet instead of offsetting, the brand works with third parties to carbon compensate clothing by supporting UN-approved clean energy projects. In the mission of carbon insetting, the Scandinavian brand now vows to work directly with its suppliers and place investments in hotspots where carbon emissions can be mitigated. In evaluating its supply chain, Ganni will no longer work with tier 1 or tier 2 suppliers that use coal-generated heat or energy by 2025. In a trial, the

總部位於丹麥的時裝品牌 **Ganni**，由 2016 年開始就為其整條價值鏈規劃碳足跡，然而，品牌並非使用抵消法則，而是選擇透過支持聯合國通過的清淨能源計劃，與第三方合作製造碳補償服飾。為投入碳回饋的使命，這個北歐品牌已承諾直接與供應商合作，並特別注資在能減少碳排放的熱點領域。Ganni 亦在評估供應鏈之後，決定在 2025 年之前終止與任何使用燃煤能源的一級或二級供應商合作；抱持著試驗性質，品牌更決定



Every cup of **Nespresso** coffee is carbon neutral, achieved after more than a decade of interventions across its value chain to reduce and remove carbon emissions from the atmosphere. Nespresso has committed itself to become a carbon insetting business by tackling emissions from its supply chain all throughout its product's life cycle and beyond, further investing in agroforestry projects and improving farmers' livelihoods. The company has replaced fossil fuels and powers its operations with renewable energy, uses biogas in manufacturing, sources low-carbon materials, and optimizes logistic

經過十多年與價值鏈各合作單位協調後，**Nespresso** 終能減少和消除大氣中的碳排放，成功讓其出品的每杯咖啡都做到碳中和。為了符合作為碳回饋企業的承諾，品牌主動解決其產品的整個生命週期間、以至及後在供應鏈上的碳排放，同時進一步投資於混農林業項目，並致力改善農民生計。公司亦已停止使用化石燃料，而改用可再生能源為營運供電，此外，也在生產過程中採用沼氣、特別採購低碳材料、及進一步

brand will build a solar plant in partnership with its longtime cotton t-shirt supplier and further support them in transitioning to renewable energy and electricity. Ganni also developed a circular business model from packaging to instore interior materials, as well as using recycled fabrics to reduce waste. The brand will be exploring next-generation fabrics and phase out virgin animal leather. Carbon insetting is a long-term investment project where the brand will evaluate its success by measuring on-site carbon and biodiversity before and after implementation before scaling with other suppliers.

與一直合作的棉質 T 恤製造商共同興建太陽能發電廠，並持續支援他們過渡至完全採用可再生能源及電力。品牌還發展出一套循環商業模式，從包裝至店內裝潢等皆選用回收紡織品製作，以減少浪費，並預備在下一階段開始探索新世代衣料，逐步停止使用原始動物皮革。品牌視碳回饋為長遠的投資企劃，將量度實施前後的實際碳排放及生物多樣性變化，去判斷措施是否成功，然後才與其他供應商探索擴展的可能性。

processes to lessen greenhouse gas emissions. Most notably, Nespresso plants trees in and around its coffee farms and invests in high-quality insetting projects. Aside from creating natural carbon sinks from tree planting, they have also been implementing pollination protection, biodiversity monitoring, and improving water provisions. Through a Nespresso training program, smallholder farmers are also encouraged and funded to practice regenerative agriculture practices in that to boost productivity and diversify farmers' incomes.

改良物流程序以減少溫室氣體排放。更不得不提的，是 Nespresso 會在其咖啡豆農場及周邊地區種植樹木，創造天然碳吸儲庫，更注資在其他高質素的碳回饋項目上，例如推動保護授粉物種、監察生物多樣性及改善供水等。而 Nespresso 的培訓計劃更成功鼓勵及資助小型咖啡農實踐再生農耕，提高生產力之餘，亦讓咖啡農民的收入更多樣化。

COMMITTED TO BECOME CLIMATE POSITIVE

承諾達成氣候正效益

BURBERRY

| | |
|--------------------|--------------------------------|
| FOUNDED 成立年份 | 1956 |
| HEADQUARTERS 總部 | London, United Kingdom 英國倫敦 |
| BURBERRY.COM | |

BURBERRY

CARBON INSETTING PROJECTS BY LUXURY CONGLOMERATE

時尚集團的碳回饋項目

KERING

| | |
|--------------------|-----------------------|
| FOUNDED 成立年份 | 1963 |
| HEADQUARTERS 總部 | Paris, France 法國巴黎 |
| KERING.COM | |



Image Courtesy: Kering



British luxury brand **Burberry** has committed itself to become climate positive by 2040 and introduced a carbon insetting project within its business to decarbonize their supply chain. The brand is also on the trajectory of reducing its operational emissions by 95% in 2022, and is already carbon neutral in the Americas region and ongoing in its EMEA and UK operations. In supporting its carbon regeneration project, it has created a regeneration fund to finance activities in tackling its environmental impact and to deliver regenerative agriculture practices within its own supply chain. The project will focus on farm-

英國高級時裝品牌 **Burberry** 承諾，將在 2040 年達成氣候正效益，並會在業務上引入碳回饋計劃，好讓其供應鏈脫碳。及至 2022 年，品牌已經成功在美洲地區實現碳中和，並持續改善歐洲、中東、印度和非洲地區 (EMEA) 及英國的營運碳排放量，有望減少 95%。而為了支持碳再生企劃，品牌特別成立再生基金，去推動用於應對環境影響的活動。品牌亦要求供應鏈實踐再生農耕法，專注於向農場提供培訓，一方面支持當地農業工

level training to improve carbon capture and storage, alongside biodiversity, ecosystem restoration, and supporting the livelihood of local producers. Burberry will be working alongside NGOs and green groups, including Pur Projet, an organization that helps companies compensate for their carbon emission through insetting and agroforestry. The project will firstly implement regenerative farming practices starting from its Australian wool producers and develop initiatives to improve carbon capture in soil, improve watershed and soil health, reduce dryland salinity and promote biodiverse habits.

作者生計，另一方面改善碳收集及儲存、提升生物多樣性及恢復生態系統。Burberry 亦同步與非牟利機構及綠色團體合作，當中包括透過碳回饋及混農林業為公司補償碳排放的 Pur Projet，讓品牌從旗下澳洲羊毛生產商著手，先實踐再生農耕法，然後訂立能提升土壤碳收集能力的方案，再改善流域、土壤健康、降低旱地含鹽量，最終促進環境的生物多樣性。



Kering, the French luxury conglomerate known for its brands from **Gucci** to **Balenciaga**, is also recognized as a global sustainable leader. Already on the pathway to becoming net-zero; the group have regular offsetting practices, and have embraced carbon insetting as part of its environmental accounting, starting by monitoring emissions from raw material sourcing in its supply chain. Gucci has already been offsetting all greenhouse gas emissions from its own operations and supply chain with forest conservation projects as the carbon-neutral luxury house continues

旗下擁有 **Gucci**、**Balenciaga** 等國際名牌的法國高級時尚集團 **Kering**，同樣被公認為全球可持續發展的領導者。集團一直以定期的抵消方式，早已走在零碳足跡的路上，更進一步將碳回饋項目納入成環境審計的一部分，由採購原材料開始就監察供應鏈的排放。當中，Gucci 亦已透過參與森林保護計劃，抵消品牌在營運及供應鏈上所產生的溫室氣體排放。縱然已經達成碳中和，這個奢侈品牌仍努力不懈地採購更

to source more sustainable raw materials to supplement its sustainable manufacturing and sourcing to reduce their carbon emissions. An environmental profit and loss tool was developed to measure and quantify the environmental impact of activities, covering carbon emissions, water consumption, air and water pollution, land use, and waste production along its supply chain. Kering's current goal seeks to convert one million hectares of farms and rangelands into regenerative agriculture by 2025 to restore and regenerate ecosystems whilst improving sourcing practices.

多可持續物料，以支援其可持續生產及採購，繼續減少碳排放。另一方面，集團亦研發出一個環境損益工具 (EP&L)，用以權衡及量化各種活動對環境帶來的影響，覆蓋範圍包括碳排放、水消耗、空氣與水源污染、土地使用以及供應鏈所產生的廢物。Kering 目前訂定於 2025 年要將 100 萬公頃的農場及牧場轉型成再生農耕，一邊恢復及復生生態系統，一邊改善採購標準。

LOW-CARBON DAIRY BRAND

低碳排放乳製品品牌

ORGANIC VALLEY

| | |
|--------------------|---------------------------|
| FOUNDED 成立年份 | 1988 |
| HEADQUARTERS 總部 | Wisconsin, USA 美國威斯康辛州 |
| ORGANICVALLEY.COOP | |



Image Courtesy: Organic Valley



Organic Valley, a low-carbon dairy brand, is launching a carbon insetting program through on-farm carbon reduction strategies and regenerative practices. While the brand has already eliminated 440 million pounds of chemicals off the land, further powered by 100% renewable electricity, its insetting program will focus on creating a carbon-neutral food system while supporting farmers with climate-smart farming practices. Organic Valley is one of the first major dairy producers to recapture all emissions on farms. The carbon insetting project will include tree plantings, improved manure

低碳排乳製品品牌 **Organic Valley** 正推出碳回饋計劃，旨在為農場策動一系列減碳排及再生措施。品牌其實早已為土地消除 4.4 億磅化學品，並已轉為使用 100% 可再生電力，但仍進一步開展碳回饋計劃，並專注於建立碳中和食物系統，同時支援農民實踐氣候智能型農業法 (Climate-smart Farming)。作為首批重新收集農場所有排放物的主要乳製品生產商之一，品牌將參與的碳回饋項目包括植樹、改良糞肥管

management, renewable energy, energy efficiency, and enhanced grazing and cropland practices. Manure management will produce less methane and increase feed efficiency, while other practices will help sequester or draw carbon from the atmosphere to lock into the soil. The company is investing in farm owners to help make improvements with climate-smart farming practices to eventually reach carbon neutrality and beyond, without reliance on carbon offsetting.

理、可再生能源、能源效益及提升放牧及農地方式。當中，糞肥管理就能確保減少產生甲烷，以提升飼料效益，而其他項目則有助從大氣截存或吸收碳，確保固存於土壤之中。品牌亦特別向農場主人注入資金，以協助他們實現氣候智能型農業法，以求共同實現碳中和、甚至更大成效，而毋須依賴碳抵消這種方式。

ADVOCATE FOR CARBON REDUCTION

減碳排放倡議者

PATAGONIA

| | |
|--------------------|-------------------------------|
| FOUNDED 成立年份 | 2000 |
| HEADQUARTERS 總部 | Copenhagen, Denmark 丹麥哥本哈根 |
| PATAGONIA.COM | |



Image Courtesy: Patagonia



Outdoor clothing and gear brand **Patagonia** has been a strong advocate for carbon reduction and is strengthening its environmental commitment through carbon insetting. The brand will be setting up a joint funding mechanism where other small brands can partner with Patagonia to invest and benefit from green factories together. In Patagonia's goal of achieving carbon neutrality by 2025, the brand will be reducing emissions from its own supply chain through green energy projects, switching to recycled and renewable energy inputs. In 2019, nearly three-quarters of all materials used in Patagonia products

作為減碳議題上堅定的倡導者，戶外服飾及裝備品牌 **Patagonia** 亦有採用碳回饋的方式，進一步實踐品牌對環境的承諾。品牌將成立聯合資助機制，讓不同的小規模品牌能與 Patagonia 合作，一起投資在綠色廠房中，並從中獲益。品牌期望能在 2025 年實現碳中和，並會透過多個綠色能源企劃，減少其供應鏈中的碳排放，繼而將資源轉投向可回收及可再生能源之上。早於 2019 年，品牌所採

were made from recycled fabrics. The brand is further developing new materials that are biobased and biodegradable, and exploring using low-emission dyeing techniques. Further investment in carbon sequestration projects to remove carbon is also taking place, including regenerative organic agriculture in nutrition soil to store carbon and reforestation projects to grow more trees.

用的生產物料之中已有接近四分之三為回收紡織物料，但時至今日，它仍孜孜不息地開發更多生物性及可生物降解的新型物料，並嘗試應用低碳染色技術。與此同時，品牌亦有投資於多個有效消除大氣碳的破固存計劃上，包括在營養土壤中開始再生有機農耕以有效儲存碳，以及透過植樹計劃種植更多樹木。

CARBON LOOPER BY H&M FOUNDATION X HONG KONG RESEARCH INSTITUTE OF TEXTILES AND APPAREL

H&M 基金會 X 香港紡織及
成衣研發中心的「CARBON
LOOPER」項目

(From left to right) Christiane Dolva, Strategy Lead Planet Positive at H&M Foundation, Martin Wall, Executive Chef at Fotografiska and Edwin Keh, CEO at HKRITA. Image Courtesy: H&M Foundation

Atmospheric carbon dioxide has rapidly increased in volume in recent decades, and according to NASA, will cause global temperatures to rise by 4.5 degrees Celsius by 2100. To combat this matter, H&M Foundation and The Hong Kong Research Institute of Textiles and Apparel (HKRITA) have come together to develop the 'Planet First' program, with aim of supporting game-changing solutions that will benefit the fashion industry, and transform the planet.

Running from 2020 to 2024, the partnership is seeking innovative technologies that will have a profound impact on the climate and those that will contribute to a planet positive fashion future. The privately-funded H&M Foundation will be donating USD12 million the Hong Kong government Innovation and Technology Fund matched by resulting in a total estimated budget of USD100 million over the five-year span.

The **Carbon Looper** is the latest project that has shown a promising breakthrough in the 'Planet First' program, where a cellulosic yarn has been developed to capture carbon dioxide from surrounding air.



H&M Foundation and The Hong Kong Research Institute of Textiles and Apparel (HKRITA) have come together to develop the 'Planet First' program, with aim of supporting game-changing solutions that will benefit the fashion industry by combating the rapid rise in atmospheric carbon dioxide and global temperature, and transform the planet. Carbon Looper is the latest supported program.

H&M Foundation 與香港紡織及成衣研發中心聯手以「Planet First」為主題，希望以支持顛覆傳統規範的解決方案，為時尚行業帶來正面改革，對抗碳排放及全球氣溫升高的考驗，並為地球帶來轉變。Carbon Looper 為計劃最新項目。

Each kilogram of Carbon Looper can absorb on average 17 to 44 grams of carbon dioxide. Captured carbon dioxide is released upon low-temperature heat and was trialed to feed plants in greenhouse. Carbon Looper garments can be reused to provide an infinite loop of carbon due to their sequestering properties. The production process itself also generates no toxic reagents and consumes little energy without the need for any special equipment, therefore can be scalable industry-wide.

If commercialized, consumers can help reduce carbon dioxide levels in the atmosphere through everyday garments. This can dispel the myths and show that fashion can have a positive effect on climate. The first supply of these carbon absorbing garments will be trialed at the photography museum Fotografiska Stockholm. Sharing the same mission of raising environmental awareness and creating positive change, servers at its in-house gastronomic restaurant will be wearing its engineered aprons and the collected carbon dioxide will be released back into Fotografiska's hydroponic garden.

近數十年間，大氣中的二氧化碳量持續迅速增加，導致全球氣溫將在 2100 年有機會進一步升高攝氏 4.5 度（資料來源：NASA）。為對抗此嚴峻考驗，H&M Foundation 與香港紡織及成衣研發中心（HKRITA）聯手以「Planet First」為主題，希望以支持顛覆傳統規範的解決方案，為時尚行業帶來正面改革，並為地球帶來轉變。

在 2020 年至 2024 年期間，此合作計劃一直致力發掘不同的創新科技，以推動它們為氣候帶來深遠的影響，同時共創地球友善的時尚未來。當中，H&M Foundation 將以私人資助形式捐出 1,200 萬美元，然後再由香港政府創新及科技基金捐出相同數目，讓為期五年的計劃取得約 1 億美元的總預算。

Carbon Looper 作為「Planet First」芸芸企劃中最新的項目，成功研發出能從四周空氣捕捉二氧化碳的纖維素紗線，實現充滿發展潛力的突破。每公斤 Carbon Looper 的紗線平均能吸收 17 至 44 克二氧化碳，並會在低溫加熱時重新被釋放。此外，品牌亦已在溫室中進行測試，確保植物吸收重新釋放的二氧化碳後能持續生長。如此隔絕式的產品特性，讓 Carbon Looper 的衣物能循環重用去無限提供二氧化碳，其製造過程亦不會產生有毒反應物，廠房亦無需添置任何特殊設備，能源消耗更相當少，讓此物料能在業界廣泛地擴展。

產品若能投入商業化生產，消費者就可以透過穿著日常服裝，幫助減低大氣中的二氧化碳含量，成功打破時裝界的迷思，推動業界為氣候造就積極影響。首批破吸收服飾系列，將在瑞典斯德哥爾摩攝影博物館 Fotografiska 內試行推出，博物館內餐廳的服務員更會穿上由 Carbon Looper 設計及生產的圍裙，展示博物館同樣擁抱提高環保意識及建立正面改變的使命；而圍裙收集到的二氧化碳，會於 Fotografiska 的水耕栽培花園中釋放，被園中植物所吸收。



GLOBAL CHANGE AWARD (GCA) BY H&M FOUNDATION

The H&M Foundation, established in 2013, is a non-profit funded by the Stefan Persson family, founders and main owners of the H&M Group. Fostering collaboration and innovation, the foundation finds, supports and shares solutions that address some of the world's most urgent challenges.

The Global Change Award (GCA) awards five early-stage innovations each year. The winners share a million Euros grant and embark on the yearlong GCA Impact Accelerator program created by H&M Foundation, Accenture, KTH Royal Institute of Technology, and The Mills Fabrica — a programme that is tailored to meet the needs of each team to help them develop and scale their innovations for impact.

The 2022 Global Change Award takes a holistic approach to seeking innovative materials, ground-breaking recycling techniques, and disruptive supply chain solutions that can reinvent the fashion and textile industry and help transform it into a planet positive one.

THE WINNERS OF GCA 2022 GCA 2022 的得獎名單



RUBI

PLANET POSITIVE VISCOSE AND LYOCCELL MADE FROM CARBON DIOXIDE EMISSIONS

由二氧化碳排放製成的地球友善人造絲 (VISCOSE) 及溶解性纖維 (LYOCCELL)



COTTONACE BY WADHWANI AI

AI PEST MANAGEMENT SOLUTION FOR SMALLHOLDER COTTON FARMERS

為小型棉花農民而設的人工智能害蟲管理方案



BIORESTORE

BIO-BASED LAUNDRY SOLUTION THAT PROLONGS GARMENT LIFE AND RESTORES TO NEW

生物基礎洗衣方案，能延長衣物壽命及將之回復成新的狀態



BIOPUFF® BY SALTYCO

USING REGENERATIVE AGRICULTURE TO MAKE A PLANT-BASED FIBERFILL

利用再生農法製造植物性纖維填充物



RE:LASTANE

CIRCULAR RECYCLING PROCESS FOR ELASTANE AND POLYESTER BLENDS

針對彈性纖維及聚酯混合物的循環回收流程

H&M 基金會
全球變革大獎



Known as the 'Nobel Prize of Fashion', the Global Change Award by the H&M Foundation, is a challenge that looks for early-stage and disruptive innovations that can help transform the fashion industry into a planet positive one.

被推崇為「時裝界諾貝爾獎」的 H&M Foundation「Global Change Award (GCA 全球變革大獎)」，旨在發掘尚在發展初段的顛覆性創意技藝，協助它們將時尚產業轉化成對地球友善的行業。

H&M Foundation 是由 Stefan Persson 家族、H&M 集團的創辦人及主要擁有人，於 2013 年共同成立的非牟利組織，目標在於促進合作及革新，發掘、支持並分享各項解決方案，以應對當今全球最具迫切的危機。

每年，GCA 都會選出 5 項早期創新項目，並向他們發放合共 100 萬歐元撥款。H&M Foundation、Accenture、KTH 皇家理工學院及南豐作坊亦為得獎者合辦為期一年的 GCA Impact Accelerator 計劃，期望配合各團隊所需，提供度身定制的支援，讓他們能發展並擴大意念，延展出更強影響力。

今年的 GCA 以整體性作考量，重點發掘創新物料、突破性回收技術及革命性供應鏈解決方案，協助時裝界重整改造，以配合聯合國提出至 2030 年推行的可持續發展目標。

GLOBAL CHANGE AWARD IMPACT ACCELERATOR

The GCA Impact Accelerator programme supports the scaling of the winning ideas through innovation, business, tech and investor readiness. The Mills Fabrica will provide industry access and mentor through investment opportunities to help winning ideas scale at speed, and refine concepts through a commercial lens to achieve real impact in today's industry.

GCA Impact Accelerator 旨在透過為得獎團隊在創新、業務、技術及投資者方面作好裝備，以支持他們擴展其意念。南豐作坊則會以提供投資機會的形式，引領及指導團隊走向業界，讓這些優秀的意念快速擴展，並從商業角度重新審視及調整概念，以求為現今的時裝界產生真正的影響。



The Mills Fabrica will provide the GCA winners with our 'impact accelerator' support, including investment readiness and peer portfolio synergies as well as industry exposure, ecosystem network and collaboration opportunities.

南豐作坊透過『IMPACT ACCELERATOR』，為 GCA 得獎者帶來各項支援，包括投資準備、同業作品集協同、業內曝光、生態系統網絡及尋找合作機會等。」



VANESSA CHEUNG

張添琳

Founder of The Mills and Group Managing Director of Nan Fung Development Ltd.

南豐紗廠創辦人及南豐發展有限公司集團董事總經理



ABOUT THE MILLS

The Mills is a landmark revitalization project from Nan Fung Group, a celebration of shared industrial legacy with Hong Kong, and a step towards a future of applied creativity and innovation.

The Mills is composed of 3 main pillars: Fabrica, Shopfloor and the Centre for Heritage, Arts and Textile (CHAT). Building on a foundation of legacy and heritage, visitors can explore the continuity of an authentic Hong Kong story, where themes of textile and industry are woven into experiences of innovation, culture, and learning.

關於南豐紗廠

南豐紗廠是南豐集團策劃的地標式保育項目，見證香港紡織工業的承傳，並帶領本地應用創意及創新產業邁進新里程。

南豐紗廠由南豐作坊、南豐店堂及六廠紡織文化藝術館三大支柱組成。項目建基於集團的承傳與歷史，並以紡織和工業為根基，交織出創新、文化及學習體驗，讓訪客從中探索不斷延續而真實的香港故事。

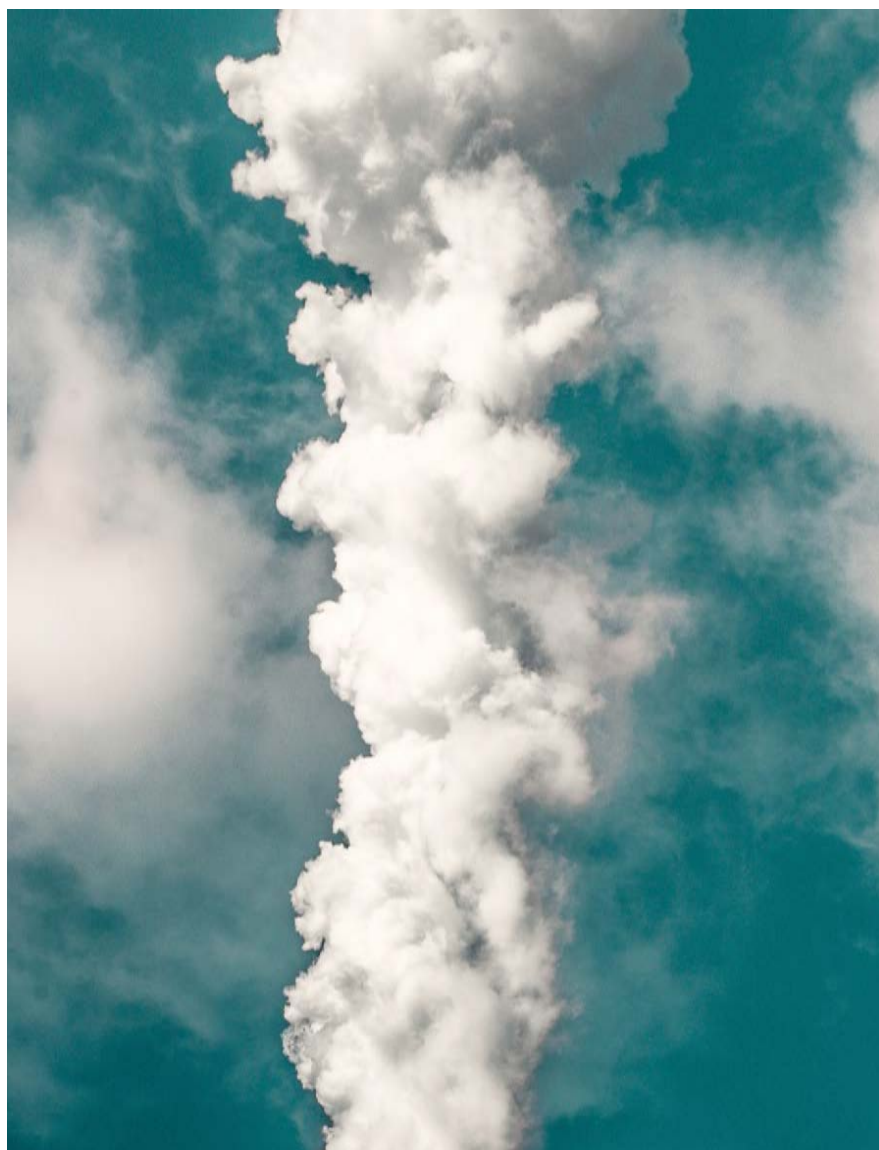


Image Courtesy: Unsplash

Contact Us

聯絡我們

Email Address 電郵

contact@themillsfabrica.com

Official Website 網站

themills.com.hk
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