Studying the Role of Ai-Driven Algorithms in Assisting the Creation of Sustainable Fashion by Optimizing Material Usage and Reducing Waste in The Design and Production Process

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Abstract
With environmental concerns and ethical considerations gaining prominence, the fashion industry is under increasing pressure to transform its practices. This study investigates the potential of AI to address these challenges through the analysis and optimization of material resources in the creation of fashion products. Key considerations include the integration of AI into design processes, the identification of the most sustainable materials, and the evaluation of AI's impact on production efficiency and cost-effectiveness. This research also addresses the implications for supply chain management, market dynamics, and consumer preferences in the era of sustainable fashion

1. Overview and Objective

The key objective of this research is to not only understand the current situation and identify and clearly define the core of the problem as it exists, but also to suggest a solution that can make a difference, using Artificial Intelligence [AI] to make it faster and more impactful.

2. Methodologies Used

Reading through various reports, research papers, brand initiatives, news articles, and web resources, as well as talking to people from the industry and a few consumers. Finally, reduction and distillation to make the report sharp and short and effective.

3. Summary

Climate change is real and is already impacting our planet in a very big way. The IPCC set out a goal for limiting global warming to 1.5ºC over the next 3 years, but the fashion industry is on a 3ºC trajectory and is not going to meet this goal. The fashion industry is the 3rd largest producer of GHG emissions in the world and is responsible, for consuming 20 trillion gallons of water, logging over 200 million trees and for polluting our oceans with around half a million tonnes of microplastics every year. The UNCTD considers fashion to be the second most polluting industry in the world after petroleum [11].

Fast fashion is leading to massive increase in consumption and overproduction. The current materials and production processes being used, and a complete lack of recycling as well as low awareness about the negative impact of fashion on our planet, are they key challenges that need to be overcome urgently. Action needs to be taken urgently and AI can augment and accelerate the process of transformation of the fashion industry. Several start-ups are already using AI effectively. AI can help reduce overproduction through predictive analysis and optimise wastage during production. It can also help create custom designed garments to reduce the need for fast fashion. From using more sustainable textiles to actually limiting the amount of stock created, many businesses have noted higher financial returns as a result of being more environmentally conscious. So, the choice to go green is really a win-win for everyone.

4. Key Sustainability Challenges

There are four key challenges that need to be addressed urgently to help reduce the negative impact of the fashion industry on our planet:

5. Fast Fashion & Over-Production

As manufacturing and shipping became significantly cheaper and faster in the late 1990's, through more efficient supply chains and new quick response manufacturing methods, a new "Fast Fashion" business model emerged and became popular across the world.

Fast fashion is the replication of recent catwalk trends and high-fashion designs, using low quality materials such as synthetic fabrics, mass-producing them at low cost and bringing them to retail stores quickly while the demand is at its highest [1,7].

Fast Fashion relies on low-cost labour from South, Southeast and East Asia, mostly women (85-90%), with labour practices that are often exploitative [1].

Several brands such as Zara and H&M quickly made fast fashion popular across the world and by 2018, the average consumption of textile fibre per person had grown to 13.8 Kg from 7.6 Kg in 1995. Around 80 billion new pieces of clothing or 60 million tonnes, are consumed every year across the world – 400% more than what this number was 20 years ago. By 2030, this is expected to rise to 100 million tonnes [4,8]. Fast fashion brands tend to overproduce, not knowing how much they will sell. In 2018, H&M ended up with $4.3 billion of unsold merchandise [2]. Every year, an incredible 50 billion garments are discarded within a year of being made [2].

It was recently reported that the giant piles of discarded clothing in the Atacama Desert in Chile, most of them non-biodegradable, can now be seen from space.

6. Unsustainable Materials
Most of the materials used in the fashion industry currently are not sustainable and we urgently need to develop more sustainable materials. Approximately 60% of all materials used by the fashion industry are made from plastic [10]. Around half a million tonnes of microplastics (tiny pieces of non-biodegradable plastic), 35% of all microplastics, are released into the oceans every year from washing clothes - the equivalent of 50 billion plastic bottles [5,10]. The effects of microplastic ingestion on marine life are catastrophic, causing starvation, endocrine disruption, stunted growth and broken digestive systems. Microplastics eventually make their way into the food chain and have been found in everyday foods such as beer, honey, sugar and table salt [12].
It's estimated that we ingest a credit card's worth of microplastic every week.

• Cotton
It estimated that around 25 million tons of cotton are produced every year.
Cotton has the advantage of being a completely natural material and therefore bio-degradable, but cotton production consumes an excessive amount of water and uses agrochemicals leading to eutrophication. Diversion of water and its pollution through cotton production has resulted in severe damage to major ecosystems such as the Aral Sea in Central Asia, the Indus Delta in Pakistan and the Murray Darling River in Australia. In India, most farmers burn residual cotton to prepare the field for the next crop rotation, and the smoke from this crop burning releases CO_2 into the atmosphere. So common is this practice, that on some days, these agricultural fires contribute to about half of Delhi's deadly pollution. However, recently, entrepreneurs are turning the unused parts of the crop into renewable energy and extra income for farmers. In Africa, turning cotton waste into briquettes and pellets, could earn farmers an additional $3 million each year.

• Polyester
Polyester made up 52% of global fiber production in 2018, at 55 million metric tons, according to a presentation by Oerlikon at ITMA 2019 (cited in Textile Exchange's 2019 Preferred Fiber and Materials Report). Polyester is a synthetic resin in which the polymer units are linked by ester groups to make synthetic textile fibres. As an oil-based plastic, polyester is not bio-degradable like natural fibres. Factories producing polyester without wastewater treatment systems can release potentially dangerous substances including antimony, cobalt, manganese salts, sodium bromide and titanium dioxide into the environment.

• Nylon
Nylon is made from crude oil and is non-bio-degradable in all its forms. Nylon manufacturing is water and energy intensive and also produces nitrous oxide, a greenhouse gas.

• MMFCs [Manmade Cellulosic Fibres]
MMFCs make up around 6.4% of the global fibre market, at 7.2 million tonnes [28].
MMFCs are made from dissolved wood pulp of trees. More than 200 million trees are logged every year for their production. Besides harming wildlife and negatively impacting ecosystems, deforestation can lead to flooding, erosion, disrupt weather patterns and even impact the macro climate [18]. However, because they're plant based, MMFC's are renewable and also bio-degradable and have the potential to be climate friendly if the wood is sourced sustainably and the processing chemicals are handled properly [28].

7. Unsustainable Manufacturing Processes
GHG Emissions
The process of converting plastic fibres into textiles is an energy intensive process requiring large amounts of petroleum and releasing volatile particulate material and acids such as hydrogen chloride [4]. Animal based fibres such as wool & leather were responsible for 14.5% of global greenhouse gas emissions in 2005 [2]. The fashion industry produces approximately 10% of all greenhouse gas emissions. Overall, the fashion industry emits more carbon than international flights and maritime shipping combined.

8. Water Consumption
It takes 700 gallons of water to produce a cotton short and 2000 gallons for a pair of jeans. And textile dyeing is the world's second largest polluter of water [4]. The global fashion industry uses 20 trillion gallons of water annually, which is 4% of all freshwater withdrawal globally and enough to meet the needs of 5 million people. And the industry is responsible for 20% of global wastewater and is the 2nd largest polluter of local freshwater in the world [2,10].

9. Unethical Labour Practices
Each piece of apparel must be handmade and fast fashion has been increasingly reliant on low-cost labour in countries like Bangladesh, India, China, Vietnam and the Philippines, mostly women and sometimes even children. This globalisation of supply chains has let to exploitation of garment workers who are treated like mere commodities by the big brands. In 2012, a fire at a clothing factory in Dhaka [Bangladesh] killed around 112 workers and just five months later again in Dhaka, the Rana Plaza disaster caused 1134 deaths when a major factory for brands

including Primark, Mango and Benetton collapsed, not because of a natural disaster, but because the building was completely neglected. Some of fashion's top CEOs earn as much as a Bangladeshi garment worker's lifetime pay in just four days.

10. Greenwashing & Lack of Awareness

Greenwashing presents a significant obstacle to tackling climate change. Several companies use greenwashing to improve the perception of their brand and to cover up the damage they're inflicting on our planet. This could include things like designing labels to evoke the natural environment, carrying out campaigns that make you believe they are eco-friendly. Here are some common tactics used [27].

• Claiming to be on track to reduce a company's polluting emissions to net zero when no credible plan is actually in place.
• Being purposely vague or non-specific about a company's operations or materials used.
• Applying intentionally misleading labels such as "green" or "eco-friendly," which do not have standard definitions and can be easily misinterpreted.
• Implying that a minor improvement has a major impact or promoting a product that meets the minimum regulatory requirements as if it is significantly better than the standard.
• Emphasizing a single environmental attribute while ignoring other impacts.
• Claiming to avoid illegal or non-standard practices that are irrelevant to a product.
• Communicating the sustainability attributes of a product in isolation of brand activities (and vice versa) – for example, a garment made from recycled materials that is produced in a high-emitting factory that pollutes the air and nearby waterways.

11. AI in the Fashion Industry

A brief perspective and current applications.
Artificial Intelligence is largely a combination of Machine Learning, Deep Learning, Natural Language Processing and Visual Recognition. In simple terms, by extracting information from large quantities of data, the technology offers insights that back creative intuition with data and can help fashion designers as well as brand owners to produce better and become more sustainable. [19]. The European Commission defines Artificial Intelligence as systems that show intelligent behaviours by analysing their environment and taking actions with some degree of autonomy, to achieve specific goals. AI-based systems can be purely software based, acting in the virtual world, or can be embedded in hardware devices such as robots, cars, drones or IOT applications [24].

12. There are essentially three types of ML algorithms:
•   Supervised Learning
•   Unsupervised Learning
•   Reinforcement Learning

Machine Learning can also happen through Neural Networks, which are networks of interconnected neurons which compute information in parallel, communicating across the linked neurons. Deep learning uses all three ML algorithms along with layers of neurons that are similar to the neurons in our brain, each layer performing a specific computation and passing the data to the layer above it. According to studies from Opus Restructuring

and Juniper Research, AI in the fashion industry has become so widespread in 2020 that 44% of UK fashion retailers who have not implemented AI are currently facing bankruptcy. As such, global spending on AI by the fashion and retail industries is predicted to reach $7.3 billion each year by 2022 [19]. By using machine learning algorithms and big data analysis, AI can help designers come up with new ideas and styles that resonate with their target audience.

13. How Ai Can Help Make Fashion More Sustainable.

There are 7 actions that are urgently required to transform the fashion industry to be more sustainable, and AI can help accelerate this transformation.

• Reduction in Production & Consumption
• Improvement in Production Processes & Supply Chain Management
• Development of Sustainable Materials
• Awareness
• Regulation
• Brand Commitment & Leadership
• Financing Circularity

14. Reduction in Consumption & Production

This is the area where maximum impact can be made and there are multiple ways in which this can be achieved. Seven key action areas are listed below which can help achieve a reduction in consumption.

•   Trend Forecasting
•   Personalised Shopping Away from Over-Consumption
•   Durability
•   Clothing Care
•   Rental
•   Recycling
•   Digital Models & Sampling

14.1. Trend Forecasting

By analysing millions of social media posts, search queries and sales data, AI can identify patterns and predict which colours, shapes and styles will be popular in the future. This not only helps fashion brands make better business decisions but also enables them to be more creative and daring in their designs, as they have more insights into what their customers want [22]. Retailers also can also optimize their inventory management by predicting trends and customer preferences. By analysing vast amounts of data, AI algorithms can help retailers stock the right items in the right quantities, reducing waste and increasing profitability.

• American footwear brand Wolverine partnered with French AI based trend forecasting company Heuritech, to launch a new product called "Windsurfer Blue" Saltwater Duck Boot in 2020 and witnessed an unheard of 100% sell-through in just 10 days, with an over 70% growth in new consumers shopping with the brand.

14.2 Personalised Shopping away from Over-Consumption

Algorithms can power personalised recommendations for shoppers, leading them to discover sustainable brands suited to their

personal preferences. Brands themselves can also take advantage of AI to study user data and purchase history, and suggest better-made alternatives, encouraging buyers to make sustainable choices.

AI can potentially ensure that every piece of clothing is made to order, perfect in style, size & fit, and produced with minimal waste.

• Wrong size is the top reason for returns of online fashion purchases, and this adds to the carbon footprint due to the logistics. My Size Inc. has designed an app that acts like a ruler and takes your body measurements through your camera. Your measurements can then be saved to shop clothes online.

• Stitch Fix a styling service, where real stylists use AI data for decision-making, is leading the way in utilising AI smarts and human stylist flair to create personalised styles for their consumers. The company uses machine learning algorithms to match what you answered in your style quiz to the products in stock from more than 1000 retailers and brands. The site even has a social impact tab that explains exactly what Stitch Fix's mission is within the sustainability space. This is a company that was built around sustainability rather than having to adapt to more sustainable models [21].

• Threadicated is using AI to offer personalised styling at scale to reduce waste. By leveraging data, AI assists stylists to match clients with products that suit their individual style, fit, shape and budget.

• EyeFitU - a try-on tool, so people are more likely to buy the right size. Fewer returns mean avoiding waste and emissions. Did you know? SANVT is using AI through EyeFitU on all product pages. This allows customers to find their perfect fit in a matter of seconds.

• Vue.ai - a completely AI-backed management suite for e-commerce retailers, powers other sustainably minded businesses like the resale website ThredUP.

14.3. Durability
One simple solution to reduce consumption is to design and build garments to last much longer and produce them with materials that have a much larger life span. Quality garments built to last as long as possible need to be produced with materials capable of longer life spans,

AI can help fashion companies adopt circular business models, where products are designed to be used, reused, and recycled. By analysing data on consumer behaviour and product life cycles, AI can identify opportunities for extending the lifespan of garments and minimizing waste.

14.4. Clothing Care
AI can help washers and dryers to weigh clothes and adjust water levels, reducing waste. It can also help in sorting, folding and water temperature adjustments preserving the lifespan of garments.

• Washing bags such as the one developed by guppy friend can reduce microfibre release by 86 per cent and captures the microfibres that do break free.

• Cora Ball can be added to loads of laundry to collect microfibres. The company says that if 10 per cent of U.S. households used Cora Ball, it would prevent the equivalent of 30 million water bottles from entering waterways per year.

• Retrofitting old laundry machines with a microfibre-catching device, such as the Lint LUV-R washing machine discharge filter, can capture fibres before they enter the environment.

14.5. Rentals & Sharing
Rental models can provide customers with access to a variety of clothes while decreasing the demand for new clothing production. China has the world's largest sharing economy, and their resale and rental fashion market is expected to account for 20% of the country's GDP by 2025.

• We have started seeing examples of specialised garments such as MUD Jeans offering high-quality denim, Vigga offering subscription for baby wear,

• Companies such as Rent the Runway are using AI to determine the stock count required for items, anticipate the season's hottest looks and ensure they have the correct sizing in store for their customers. RTR collects a wealth of internal customer data on rental selections, designers, and shopper tendencies (regional, age-specific) then utilizes this data to create a unique shopping experience. RTR interprets supervised learning outputs with the aid of stylists to predict consumer preferences, suggest rentals, and push add-ons. In addition, RTR uses reinforced learning to analyse unreported customer behaviour on their interface [21]. Through unreported and reported customer data RTR can identify trends to influence their future assortment decisions, focused on increasing both the quantity and quality of items available to renters, and glean insights for innovations that could improve their back-end interface.

In the short-term RTR is also focused on minimizing their risk in the rental market. They use machine learning to identify correlations amongst consumers that have lost, stolen, or damaged rentals that allows them to screen for potential abuses and minimize their exposure going forward. In the long-term machine learning insights drive RTR's core projects and new product offerings. The Company's introduction of a subscription-based option and their recent move into brick-and-mortar, in which customers can exchange rentals, were both driven by machine learning enabled customer-insights and are continually improved upon utilizing data.

• In India, rent it Bae has a similar concept of renting clothes online

14.6. Recycling
Recycling textiles is complex because textiles incorporate so many material blends and therefore, efficient and accurate textiles sorting is critical to cost effectively scale circularity efforts.

AI powered automated decision support tools can help solve this problem.

• The Research Institute of Sweden [RISE] and Wargon Innovation are partnering with the Red Cross, Myrorna, BjorkaFrihet, Texaid, Minikit and ShreTex in this area.

• Sarika Bajaj from Carnegie Mellon, along with two co-founders, set up Refiberd to create a sorting and recycling system that uses AI and robotics to turn post-consumer textile waste into thread. This system "has the potential to eliminate 93% of global textile waste", the company claims. Garments are first sorted by colour and then shredded and finally sorted by fiber type with the help of AI. Spectroscopy is used here – shining a light on the material and that light reflects back, producing a graph of how it interacted with the material. AI is then able to learn from the different graphs and approximate what the material is. Once the material has been sorted, it undergoes Refiberd's patented chemical recycling procedure, creating polyester and cellulosic thread which is compatible with existing manufacturing techniques for making new garments.

• ThredUP and Poshmark have created platforms for buying and selling used clothes. Through AI, thredUP is able to visually tag second-hand clothing, describing necklines, size, colour, label name, wear, tear etc., allowing the company to put a suitable resale value on these items.

14.7. Digital Models & Sampling

Digital fashion involves creating AI generated 3D models and virtual garments that can be worn by avatars or superimposed onto real-life images, without the need for physical production. This not only saves resources (companies often require upto 20 samples) but also opens up new possibilities for creativity and self-expression, as consumers can experiment with different styles and looks without the financial or environmental cost.

• A Dutch fashion start-up Lalaland creates fashion models, or avatars, for e-commerce brands to showcase their products without having to a real photoshoot and hire real models. Brands can customise the model's hair, skin tone, body shape and everything else to match their potential clientele in just five minutes.

• In 2018, IBM teamed up with Tommy Hilfiger and FIT [The Fashion Institute of Technology] Infor Design and Tech Lab to produce key insights on trends to expedite the initial design process and to better predict demand for hyper-localized products. This was done by applying computer vision, natural language understanding and deep learning across 15,000 of Tommy Hilfiger's product images, 600,000 publicly available runway images and nearly 100,000 patterns from fabric sites, resulting in key silhouettes, colours and novel prints and patterns that could be used as informed inspiration to the designers. The resulting 3D designs were then used by FIT senior Grace McCarty to design a plaid tech jacket incorporating a special thread embedded in a removable, futuristic plaid panel with IBM's Watson's Tine Analyzer, which responds in near real-time to the sentiment in a customer's social media accounts [17].

15. Improvement in Production Processes & Supply Chain Management

15.1. Optimising Waste

AI powered tools can be used to reduce the amount of fabric waste that is generated during the design process. AI algorithms can analyse the patterns of a design and automatically adjust the size of the fabric pieces to reduce excess scrap fabric and a cut and sew manufacturer can utilize AI-driven cutting systems to optimize fabric usage and minimize waste.

15.2. Production Efficiencies

AI-based solutions can provide real-time data and analytics, allowing brands to track and monitor their entire production process to identify inefficiencies and make data-driven decisions to improve resource (energy and water) consumption [16].

15.3. Sourcing Raw Materials

AI can look at a garment design, identify the materials needed, and make suggestions based on set parameters - such as natural fibres, suppliers with no history of violations, and so on [16].

15.4. Traceability

Traceability systems powered by traceability software and big data can help fashion brands reach far into their supply chains to understand the entire life cycle of their products, from sourcing of raw materials, to manufacturing and shipping the final product, a key enabler for sustainability road maps [23].

• Prewave, a German AI company that allows clients to monitor suppliers. It combs the internet for any possible information on sustainability violations related to the environment, labour, governance (i.e. corruption) - and sends risk alerts. Although they don't operate in fashion just yet, they're an example of a powerful tool for businesses that truly want to pursue sustainability [16].

16. Development of Sustainable Materials

AI-powered tools can help designers discover and develop new sustainable materials. By analysing the properties of existing materials, these tools can suggest alternatives that are more environmentally friendly and have a lower carbon footprint. There are already quite a few start-ups exploring several different ideas for new sustainable materials.

• Tandem Repeat, founded in 2017, by co-founders, Dr. Gozde Senel Ayaz, Dr. Benjamin Allen, and Dr. Melik Demirel, is revolutionizing sustainable fashion with ith's AI designed squid proteins that offer unparalleled strength, durability and sustainability. Squitex technology is a non-polluting replacement for petroleum and animal-based fibres. The company recently announced its first fashion garment, the Squitex. The Squitex an AI-designed protein-based fiber made from biomanufacturing. Plastics break down into microfibers found in everything, but Squitex can minimize microfiber pollution by using Nature's genetic codes," said Dr. Melik Demirel, co-founder and Huck Endowed Chair Professor in Biomimetic Materials at Penn State. He added, "Our team combines biomanufacturing and artificial intelligence to fine-tune the physical properties of Squitex for

various tasks, which includes predicting protein sequences and structures, as well as designing garments" [15].

• AMSilk is the world's first industrial supplier of vegan "spider" silk. The German start-up uses a patented biotechnology to create a smart, silk-like formulation that can be used to replicate that luxury silk-like quality in clothing. AMSilk's unique bio-fabrication process uses the blueprint for silk from the genome of a spider and reprograms the microorganisms to enable them to produce silk polymers. By studying the unique DNA coding in spiders themselves, scientists can copy their super strong silk-making strategies, using bacteria and natural fermentation processes to produce a similar material at scale [34].

• Agraloop, a textile innovation arm from US based start-up Circular Systems, is using agricultural waste from food and medicine crops including pineapples, bananas, oilseed and CBD hemp to create boifibre. Using a special wet processing technique, they extract cellulose fibres from plant stems and leaves which are then purified into soft fibre bundles which can be spun into fabric yarn.

• Based in Finland, Spinnova has developed breakthrough technology for making cellulosic textile fibre out of wood or waste, such as leather, textile or food waste, without harmful chemicals. The wood pulp is FSC certified [29].

• Infinited Fiber Company [IFC], also located in Finland, can process paper, card, textile and agri-waste into pulp which then becomes cotton-like fibre. These fibres can be used in wide range of woven and non-woven textiles, from jeans to t-Shirts and wipes. Their technology includes patented processes for both waste pulp creative and wet spinning into Infinna fibers. During fiber spinning, IFC uses urea and water to transform their waste pulp into Infinna fibers [29].

• Renewcell based in Sweden, uses 100% textile waste to make recycled pulp that is a direct replacement for wood pulp currently used by textile producers. Renewcell plans to partner with IFC and Spinnova rather then compete with them, because Renewcell's recylcled pulp combined with IFC's and Spinnova's solvent-free fiber processing stands to offer a cumulatively lower-impact fiber, compared with tranditional MMFCs [29].

• Spain's Ecoalf creates shoes from algae and recycled plastic as part of its Upcycling the Oceans collection. Founded by Javier Goyeneche in 2012, Ecoalf collects ocean plastics from 33 ports and turns the trash into shoes, clothing and bags.

• In Amsterdam, GumDrop collects gum and turns it into a new kind of rubber, Gum-tec, which is then used to make shoes in collaboration with marketing group I Amsterdam and fashion company Explicit. GumDrop says around 3.3 million pounds of gum end up on Amsterdam's paths every year, costing millions of dollars to clean. It takes around 2.2 pounds of gum to make four pairs of sneakers.

• Outdoor gear retailer Patagonia, based in California, has been producing fleece jackets using polyester from recycled bottles since 1993, working with Polartec, a Massachusetts-based textile designer. Patagonia also encourages shoppers to buy only what they need, and mends and recycles older items.

• Gothenburg-based Nudie Jeans uses organic cotton for its jeans and offers free repairs for life. Customers also get a discount if they hand in their old jeans.

• Cambodia-based Tonlé uses surplus fabric from mass clothing manufacturers to create zero-waste fashion collections. It uses more than 97 per cent of the material it receives and turns the rest into paper.

• In the Netherlands, Wintervacht turns blankets and curtains into coats and jackets. Designers Yoni van Oorsouw and Manon van Hoeckel find their raw materials in secondhand shops and sorting facilities where donations are processed. San Francisco- and Bali-based Indosole turns discarded tyres in Indonesia into shoes, sandals and flip-flops, while Swiss firm Freitag upcycles tarpaulins, seat belts and bicycle inner tubes to make their bags and backpacks.

• In New York, Queen of Raw connects designers, architects and textile firms with dead stock of sustainable fabrics from factories, brands and retailers. Queen of Raw says more than US$120 billion worth of unused fabric sits in warehouses, waiting to be burned or buried.

• Novel Supply, based in Canada, makes clothes from natural and organic fabrics and is developing a take-back programme to find alternative ways to use garments at the end of their life. For founder Kaya Dorey, winner of UN Environment's Young Champion of the Earth award in 2017, the aim is to create a zero-waste, closed-loop fashion model.

• Lifestyle brand and jeans manufacturer Guess said it was teaming up with i:Collect, which collects, sorts and recycles clothes and footwear worldwide, to launch a wardrobe recycling programme in the US. Customers who bring in five or more items of clothing or shoes, will receive discounts. Wearable items will be recycled as second-hand goods, while unwearable items will be turned into new products like cleaning cloths or made into fibres for products like insulation. [9]

17. Awareness

There is an urgent need to Improve awareness about the impact of fast fashion on our planet. Marketing strategies used by sustainable brands need to communicate sustainable strategies clearly to consumers.

Provide complete data on the costs to the environment – for the production of each garment – similar to the data on food packaging.

For those that are sustainable-first consumers, AI has made it possible for you to find the kinds of fashion that suit your set of ethics. More and more people have shifted to purchasing items online. Now you can ask Alexa (or any other virtual assistant), for recommendations for a pair of shoes that fit your outfit from

stores that actually sell sustainable merchandise. Looking for those businesses and brands that have developed more environmentally friendly practices has never been so easy. Furthermore, your virtual assistant is able to keep track of the stores you purchase from the most so that you're offered options that fit your style and taste.

18. Regulation
In an ideally regulated fashion industry, consumers should not be required to become experts on greenhouse gas emissions or ethical working conditions or polluting chemicals. In the EU, if you're buying a mouthwash, you can be sure that the concentration of triclosan is a maximum of 0.2% in order to protect aquatic life when it washes down the drain. Someone behind the scenes has addressed it as a law [33].

18.1. Broadly, the regulations required, could be grouped into two categories:
Laws affecting what a brand can or must say.
"Some laws require that brands disclose certain information, such as how they address the risk of modern slavery in their supply chain," says Renouf. "Others regulate what they can say." For example, many countries prohibit "misleading statements" and there are recent EU proposals to specifically ban some forms of greenwashing [33].

18.2. Laws impacting what a business can or must do.
Laws can prohibit businesses from engaging in certain poor practices. For example, in the EU, the REACH laws on hazardous chemicals prohibit the use of certain Azo dyes as they are associated with a risk of cancer. Customs laws in the US prohibit the import of good made with forced labour [33].

And it's not just up to the politicians – in many countries, the voices of citizens are making a difference [33].

19. Brand Commitment & Leadership

It's only a matter of a few years before sustainability becomes unavoidable for the fashion brands and therefore, the ones that take the lead now will benefit from the head-start they have over others. Brands need to change the Metrics of Success and start deploying the Triple bottom-line accounting system.

19.1. Increase Transparency to Reduce the Information Gap.
It takes too much effort for consumers to determine whether clothes are sustainable.
To overcome this barrier, in-store displays, labels, and product descriptions need to be clear, easily available, and reliable. Best-in-class brands already include supply chain and partner information, material descriptions, and stories about the communities involved in the making of their clothing. Shedding light on their production processes engages consumers in a genuine and transparent way. Product packaging is another means to communicate (and practice) sustainability [32].

Engage customers on product durability and impact per-wear information.
Strategically, brands can present durability, quality, and sustain-

ability in the same thread. If brands position fashion as an investment rather than a short-term or seasonal purchase, quality can become a gateway to more sustainable shopping, even among the least-concerned consumers. Brands can engage consumers on durability by including information, such as impact-per-wear or the expected life span of a garment, on product tags or labels [32].

Make sustainable shopping more convenient and appealing.
Brands can use store zoning and dedicate space for sustainable products and displays. They can also invest in salesforce training to help consumers find, understand, and purchase more sustainable products. Activities that increase transparency also increase appeal. For example, storytelling about a garment's origins or source materials helps consumers distinguish a product as sustainable and creates positive associations with the purchase.

Make sustainability their statement piece.
Brands that proactively design sustainability into their strategy and operations will cement their relevance and capture a windfall of unmet demand, now and into the future. Most consumers want to purchase more sustainably; they just need help doing so. Storytelling about a garment's origins or source materials helps consumers distinguish a product as sustainable and creates positive associations with the purchase [32].

20. Financing Circularity
The financing opportunity in fashion is between $20 to $30 billion per annum until 2030.

An extensive pipeline of innovations has emerged from new, alternative raw materials right through to digital platforms. Bringing these innovations to scale requires industry support and financing to advance solutions from R&D to fully commercialized products.
"Soft tech" solutions such as digital platforms have attracted more financing than the more asset-intensive forms of "hard tech" such as new raw materials or recycling technologies. However, hard tech innovations will spark the larger transformation towards sustainability and therefore have a greater need for financing per year.

In recent years, Morgan Stanley has helped mobilize investor capital and grow the sustainable and circular fashion market by facilitating initial public offerings and sustainable bond issuances that help scale innovation. The companies featured below are just a small sample of those working across the fashion value chain to advance solutions that are critical for greening the fashion industry.

Support the efforts of customers to maintain their clothes for longer.
Introduce more clothing services, such as garment restyling or consulting, advice on upgrades, customisation, and mending at home. Retailers could provide repair and other services in-store and form partnerships with repair and restyle providers based in local communities. Several brands already offer in-store repair and incentivise users to keep their garments well maintained, in particular, outdoor clothing brands such as Bergans, Jack

Wolfskin, Patagonia, Salewa, and Houdini, all offer repair services for their used products. Patagonia operates the largest (and still growing) repair facility in North America, repairing about 50,000 pieces per year [31]. Design Copyright and IP protection is a potential problem – since most data is on the cloud and can be hacked.

21. Definitions
21.1. Circular Economy
A framework designed to decouple economic activity from the consumption of finite resources, focusing on positive societal and environmental impacts. Its core principles are: a) Eliminate waste and pollution. b) Circulate products and materials at their highest value c) Regenerate nature. d) Transition to renewable energy and materials

21.2. Computer Vision
This is the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images, and the extraction of high-dimensional data from the real world in order to produce numerical or symbolic information, in the forms of decisions. Understanding in this context means the transformation of visual images (the input to the retina in the human analog) into descriptions of the world that make sense to thought processes and can elicit appropriate action [25].

22. Data Mining
An AI based technique to extract meaningful data from collections of big data.

23. Decarbonize
Refers to all measures through which an organization reduces their carbon footprint, primarily GHG emissions, in order to reduce impact on the climate

24. Downcycling
To recycle in such a way that the resulting product is of a lower value than the original

25. ESG
Environmental and social governance (ESG) criteria are a set of standards beyond the typical financial factors that help companies make informed investment decisions. Investors are increasingly using this data and metrics to screen potential investments.

26. Eutrophication
Eutrophication is caused by nitrates and phosphates from fertilizers & pesticides running into rivers and lakes, promoting the growth of algae and other plant life which take oxygen from the water, causing severe damage to fish.

27. Greenwashing
Marketing which misrepresents environmental impacts or benefits, leading people to believe that a company's products or policies are better than they are

28. GHG Emissions
Greenhouse gases are carbon dioxide (CO_2) and methane (CH_4) emitted from human activities which trap heat in the atmosphere resulting in global warming.

29. IPCC
The Intergovernmental Panel on Climate Change is the United Nations body for assessing the science related to climate change.

30. Material Circularity
Refers to a material's ability to be circulated i.e., recycled multiple times. Materials must have some content from existing recycled sources, packaging or industrial by-products.

31. Natural Language Processing [NLP]
A branch of AI that helps machines understand and process natural human language.

32. Net Zero
Reaching net-zero emissions and becoming carbon neutral. Many companies across all industries have publicly declared targets to become carbon neutral by 2050.

33. Renewable Energy
Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed.

34. Sustainability
Meeting our own needs without compromising the ability of future generations to meet their needs. In addition to natural resources, concerns for social equity and economic development are considered.

35. Triple Bottom Line
A sustainability framework that measures a business's success in three key areas: People, Planet and Profit.

36. Waste Hierarchy
A waste management framework prioritizing efficient use of resources and reduction of environmental harm. Reduce - Reuse - Repair - Share – Recycle [33].

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