

DNA AND THE TEXTILE INDUSTRY: FROM RAW MATERIAL TRACKING TO BRAND PROTECTION. HOW GENETICS IS CHANGING TEXTILE PRODUCTION

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Adopting DNA technologies in the textile industry requires significant initial investment for infrastructure and system integration. However, the return on investment (ROI) is achieved through reduced counterfeit risks, enhanced supply chain efficiency, and access to premium markets that prioritize sustainability and ethical sourcing. Smaller manufacturers may face challenges with high upfront costs, but strategic partnerships with technology providers can help mitigate financial burdens and enable gradual adoption. DNA-certified supply chains attract investors focused on Environmental, Social, and Governance (ESG) metrics, increasing market appeal. The main economic factors to consider include initial investment, ROI, scalability, and consumer willingness to pay a premium for ethically sourced products. Effectively balancing these elements can drive long-term profitability, reshape market positioning, and help companies comply with sustainability regulations, positioning them for success in the evolving ethical fashion market. DNA tagging systems enhance brand trust, ultimately boosting sales and market share among eco-conscious consumers. .

DNA technologies have emerged as transformative tools across various industries, including textiles. The integration of genetics into fabric production is a revolutionary development, significantly impacting the textile industry. From genetically engineered fibers to DNA-based traceability, the economic benefits are becoming more apparent as new technologies reshape supply chains, manufacturing processes, and consumer



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demand. Their applications range from ensuring supply chain transparency and product authentication to enabling sustainable practices and advancing material science. The economic implications of integrating DNA technologies into the textile industry are profound, influencing production costs, market dynamics, and regulatory compliance. Adopting DNA technologies offers a significant competitive advantage in the textile industry by enabling brand differentiation, improving global trade facilitation, and driving product innovation. Companies leveraging DNA-based solutions for sustainability and traceability can stand out in a crowded marketplace, attracting socially responsible consumers. DNA-enabled traceability simplifies compliance with international trade laws and certifications, reducing trade barriers and expanding market access. Furthermore, the integration of genetic modifications and biofabrication allows textile companies to introduce innovative products with unique qualities, such as higher durability, biodegradability, and sustainability, thereby commanding premium prices¹.

The growth of genetic technologies in textiles is driving innovation and creating job opportunities, particularly in bioengineering, genetic research, and textile manufacturing. As genetically engineered fibers and sustainable textiles gain traction, there is an increasing demand for skilled professionals in biotechnology and materials science. This growth is expected to lead to the establishment of new industries focused on sustainable fashion technologies, further advancing the sector.

For SMEs adopting genetic technologies, investing in workforce training and development becomes essential. As new production techniques are integrated into manufacturing processes, employees will need to acquire the necessary skills to work with these advanced technologies. This shift

not only fosters a more skilled workforce but also opens up educational opportunities for both current and future employees, driving innovation and enabling SMEs to play a key role in the evolution of the industry².

DNA technologies also bring significant cost benefits. By enabling in-situ production of high-performance fibers through microbial synthesis, these technologies can reduce the resource-intensive processes traditionally involved in textile manufacturing. Genetically modified crops, such as Bt cotton and hemp, can produce fibers with higher yields per acre, lowering raw material costs and increasing the availability of cost-effective, high-quality fibers. Additionally, bio-based fabrics like mycelium leather and spider silk reduce dependency on petroleum-based materials, offering a more stable cost base and insulating manufacturers from price volatility in the oil market. The ability to engineer crops for greater efficiency—such as water-efficient GM cotton—can reduce the strain on water resources, lowering agricultural costs and improving the sustainability of the supply chain. Moreover, DNA technologies enable the production of biodegradable and recyclable fibers, which help reduce the environmental impact of textiles and lower costs related to waste management and recycling. From an economic standpoint, these advances help companies meet eco-regulations more efficiently, reducing costs associated with environmental compliance and potentially lowering tax burdens. As consumers increasingly demand verified sustainable practices, regulatory bodies are incentivizing these efforts with subsidies and tax benefits. DNA-tagged sustainable materials simplify compliance, positioning companies to benefit from both regulatory support and consumer preference for eco-friendly products.

High-performance fibers, produced through DNA-modified organisms, offer

¹ Ellis K., Applied DNA Sciences: DNA Technology & Tagging Shines the Light on Trade Rule Evasion and Labor Abuse in Supply Chains December 13, 2022, <https://textilesinthenews.org/applied-dna-sciences-dna-technology-tagging-shines-the-light-on-trade-rule-evasion-and-labor-abuse-in-supply-chains/>

² Sustainable Textiles: Role of Biotechnology In Eco-Friendly Fashion, <https://www.globaltextiletimes.com/articles/sustainable-textiles-role-of-biotechnology-in-eco-friendly-fashion/>

TABLE 1

Cost-Benefit Analysis of DNA technologies in the textile industry

Category	Costs	Benefits
Initial Setup	<ul style="list-style-type: none">❖ DNA tagging equipment and systems installation❖ R&D expenses for DNA-modified materials❖ Training and education for staff	<ul style="list-style-type: none">❖ Brand protection from counterfeiting❖ Higher ROI through premium pricing for authentic products
Operational Costs	<ul style="list-style-type: none">❖ Regular testing and tagging❖ Licensing fees for DNA technologies❖ Maintenance of systems	<ul style="list-style-type: none">❖ Improved supply chain efficiency❖ Avoidance of penalties for non-compliance with environmental laws
Scalability Costs	<ul style="list-style-type: none">❖ Upgrading systems to handle increased production❖ Integrating DNA tech into diverse product lines	<ul style="list-style-type: none">❖ Entry into niche markets like luxury or eco-conscious consumers❖ Long-term cost savings from reduced fraud and waste
Market Risks	<ul style="list-style-type: none">❖ Consumer reluctance to pay premiums❖ Competitive pressure to lower prices	<ul style="list-style-type: none">❖ Enhanced customer loyalty❖ Increased investor interest in ESG-compliant brands

exceptional properties such as enhanced strength, elasticity, and moisture-wicking capabilities. These advanced fibers cater to specialized markets, including sportswear and protective clothing, where performance and durability are critical. For example, bio-based spider silk, a high-performance fabric, presents a superior alternative to traditional materials, appealing to both luxury brands and niche high-tech markets that prioritize sustainability and innovation³. In addition to performance, DNA technologies enable greater transparency and authenticity in material sourcing. Applied DNAS ciences, for instance, uses molecular tagging for cotton to ensure its origin, helping combat the prevalence of fraudulent organic cotton. This technology not only protects brands from counterfeit goods but also supports their sustainability claims, fostering trust with consumers. Through partnerships with global brands like Himatsingka, DNA tagging has contributed to increased revenue by enhancing brand credibility and securing premium market positions⁴. Bioengineered silk is another significant innovation in the textile industry. Spider, a leader in bioengineering, developed Brewed Protein™, a silk alternative synthesized through DNA-

modified microbes. This technology enables the creation of environmentally friendly outdoor wear, in collaboration with brands like The North Face. Although the initial production costs for such bioengineered fibers are high, they are offset by the strong demand from eco-conscious markets willing to pay premium prices for sustainable, high-quality products. These developments in bioengineered fibers, such as spider silk, are not only biodegradable but also have a low carbon footprint, aligning with the growing consumer preference for sustainable fashion solutions⁵. Overall, DNA technologies are playing a pivotal role in the creation of high-performance, sustainable fibers that are shaping the future of the textile industry. By offering superior quality and supporting sustainability claims, these fibers are enabling brands to tap into premium markets, drive revenue growth, and meet the increasing demand for eco-friendly and ethically sourced products.

As consumer demand for sustainable and ethically produced goods grows, textiles made from genetically engineered fibers and bio-fabricated materials are commanding higher prices. Leading brands such as Stella McCartney and Patagonia have capitalized on

³ Fernández C.R., Biotechnology is Changing How We Make Clothes ,February 25, Updated on June 24, 2022, <https://www.labiotech.eu/in-depth/biofabrication-fashion-industry/>
⁴ STONY BROOK, N.Y. Applied DNA Enters into Multi-Year Commercialization Agreement with Indus Group for Large-Scale Implementation of CertainT Cotton Traceability,July 25, 2024, <https://certaint.com/applied-dna-indus-agreement-certain-cotton-traceability/>
⁵ Peters A. This jacket's threads were inspired by spider silk and 'brewed' in a factory, 10-31-2019.

this trend by positioning their products as eco-conscious, appealing to environmentally aware, high-end consumers. For instance, Stella McCartney uses mycelium-based, DNA-tagged leather to ensure traceability and enhance the sustainability of its luxury fashion lines, giving it a competitive edge in the eco-conscious market⁶. DNA technologies contribute to sustainability by reducing waste, improving material efficiency, and promoting eco-friendly production methods. Through DNA analysis, companies can optimize raw material use, minimizing waste and lowering production costs. Additionally, DNA-based fibers like spider silk and algae textiles are biodegradable and attract consumers willing to pay a premium for sustainable options. Moreover, DNA technologies support regulatory compliance by enabling companies to meet tightening environmental regulations. These advancements help businesses comply with sustainability requirements, reducing penalties and gaining access to government subsidies for sustainable practices. By incorporating genetic improvements into production, companies can adhere to stricter regulations on chemical use, waste reduction, and environmental impact, driving both compliance and profitability. DNA-based traceability aligns with global shifts towards sustainability in the textile industry. By using genetic markers to verify the origin and type of fibers, companies can meet the rising consumer demand for transparency, which is crucial for building brand loyalty and enhancing market reputation. As consumers increasingly prioritize ethical practices and sustainability, DNA technology serves as a

valuable tool for brands to showcase their commitment to these values.

Fashion brands are ready to change the game with the ultimate goal of ‘good for people and planet’. The global ethical fashion market is expected “to grow to \$9.81 billion in 2025 and \$15.17 billion in 2030 at a CAGR of 9.1 percent” as per the numbers by sustainable fashion industry statics⁶, driven by this surge in demand for eco-friendly products. Moreover, over 60% of millennials and Gen Z consumers prefer sustainable products and are willing to pay a premium for apparel made with environmentally friendly practices. Luxury buyers, in particular, are willing to pay 25-30% more for products with traceable origins, underscoring the financial potential for brands that embrace DNA-based traceability⁷. Additionally, DNA technologies are facilitating circular practices in the textile industry, enabling textile recycling and reducing waste. This further aligns with the broader push for sustainability in fashion, creating new opportunities for companies to enhance their offerings while contributing to a more sustainable future.

Below is a comparative analysis showing estimated costs and benefits for implementing DNA technologies (Charts for Cost-Benefit and ROI Analysis).

ROI Summary (Sustainable Apparel)

- Initial Investment: ~\$100,000 - \$200,000 (equipment + setup).
- Annual Benefits: ~\$300,000 - \$750,000.
- ROI: Achieved within 1-2 years, depending on market reach and scale.

TABLE 2

Demographic	Preferences	Implications for SMEs
Eco-Conscious Shoppers	Prioritize sustainability certifications	Market products with eco-labels and DNA tracking.
Luxury Buyers	Demand authenticity in premium materials	Focus on DNA-tagged high-value items like silk.
Gen Z & Millennials	Prefer brands that are transparent and ethical	Leverage traceability as a marketing strategy.

⁶ Wightman-Stone D.,Stella McCartney to launch first commercial luxury bag crafted from mycelium, May 23, 2022, <https://fashionunited.com/news/fashion/stella-mccartney-to-launch-first-commercial-luxury-bag-crafted-from-mycelium/2022052347742>
⁷ V. Sharma,Why Retailers are Betting Big on Sustainable Fashion? Mar 11, 2021, <https://www.indianretailer.com/article/sector-watch/fashion/why-retailers-are-betting-big-on-sustainable-fashion.a6887>
⁸ Noori K ,The Sustainable Fashion Industry Statistics 2024 July 18, 2024 <https://creedvintage.com/blogs/blog/sustainable-fashion-statistics>

TABLE 3

Cost-Benefit Chart for Sustainable Apparel Sector

Cost Category	Annual Cost Range (USD)	Economic Benefit Category	Annual Benefit Range (USD)
DNA Tagging Systems	\$50,000 - \$100,000	Premium Pricing	\$150,000 - \$300,000
Training and Integration	\$10,000 - \$25,000	Brand Protection (Anti-Fraud)	\$200,000 - \$500,000
Maintenance and Testing	\$20,000 - \$50,000	Market Access via Compliance	\$100,000 - \$250,000
Sustainable Fiber Production	\$75,000 - \$150,000	Reduced Resource Costs	\$80,000 - \$200,000

TABLE 4

ROI Deep Dive: DNA Technologies in Sustainable Apparel⁹

	Organic Cotton Certification	Circular Fashion Implementation
Problem:	Fraudulent claims of organic cotton inflate costs and erode trust.	Consumers demand circular practices; brands face challenges in verifying recycled content.
Solution:	DNA tagging ensures transparency.	DNA markers tag recycled fibers to ensure authenticity.
Investment:	<ul style="list-style-type: none">\$75,000 for DNA tagging systems in the first year.\$20,000 annually for maintenance.	<ul style="list-style-type: none">\$100,000 setup for DNA-tracked recycling systems.\$30,000 annual operational costs.
Outcome:	<ul style="list-style-type: none">Secures contracts with retailers demanding verified organic materials.Adds \$250,000 annually in premium contracts and reduced fraud costs.	<ul style="list-style-type: none">Access to \$500,000 annual revenue from sustainable fashion markets.Savings of \$100,000 in raw material costs annually.
ROI	First-year ROI of ~200%	First-year ROI of ~470%

ROI Breakdown for Sustainable Apparel (Investment vs. Benefits over time).

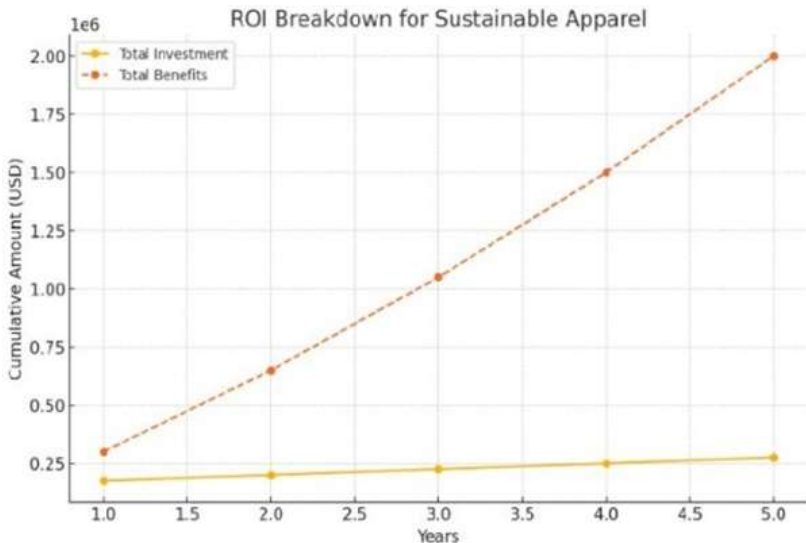


CHART 1

Cost-Benefit Analysis for DNA Technologies in Apparel

A cumulative comparison of investment and benefits over five years, showing significant returns by year two.

⁹ By Fashion's new must-have: Sustainable sourcing at scale| Report

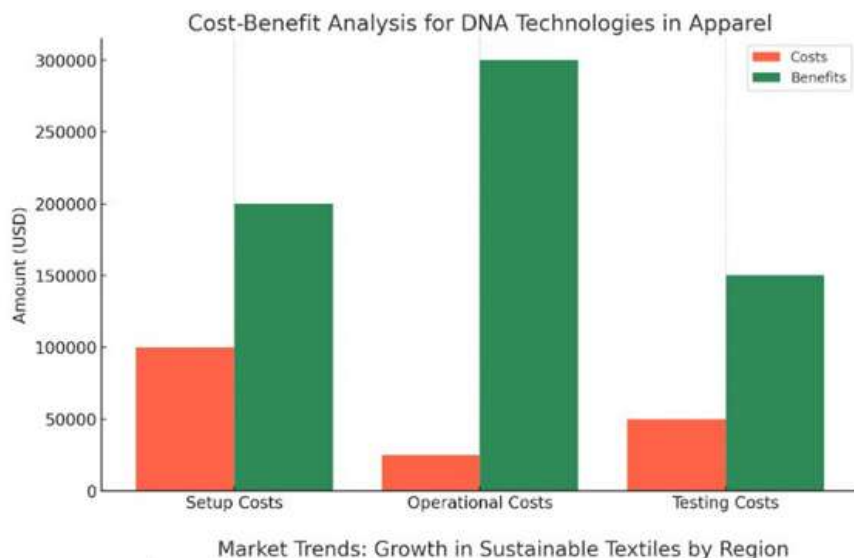


CHART 2

Cost-Benefit Analysis for DNA Technologies in Apparel (Initial and operational costs vs. gains)

Cost-Benefit Analysis for DNA Technologies in Apparel:

Side-by-side comparison of setup, operational, and testing costs versus benefits like fraud prevention and market access.

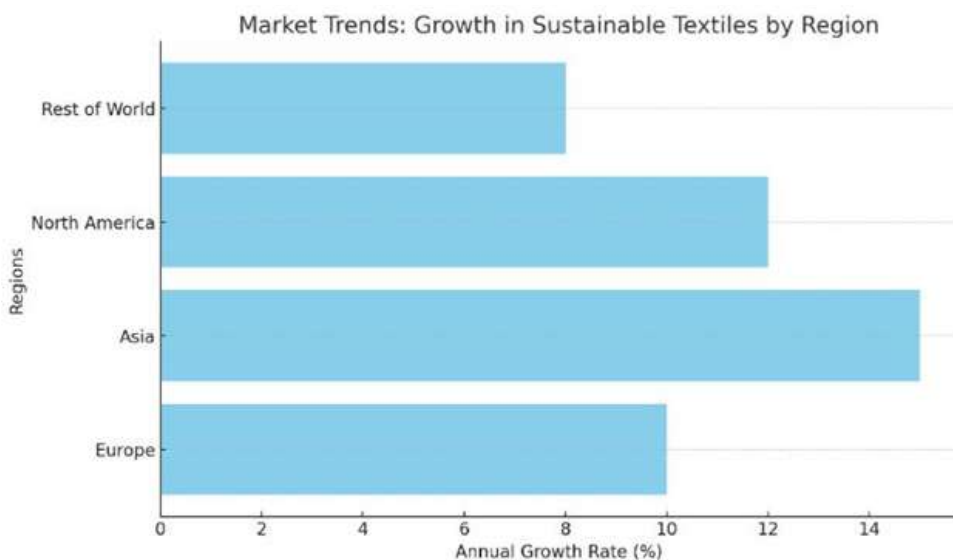


CHART 3

Market Trends (Growth in sustainable textiles by region)

The adoption of sustainable textiles is experiencing rapid growth globally, with notable trends emerging in both Asia and Europe. In Europe, high adoption rates of sustainable textile practices can be attributed to strict environmental regulations, such as the EU’s Textile Strategy, which aims to make the textile sector more sustainable and circular. These regulations are driving brands and manufacturers to adopt sustainable practices, including DNA tagging and other traceability technologies, to meet compliance standards and cater to increasingly eco-conscious consumers. Europe’s leadership in sustainable textile adoption is fueled by these policy-driven initiatives, which encourage businesses to innovate and prioritize environmental responsibility.

In Asia, the interest in sustainable textiles is also growing, particularly in key textile hubs like India and China. These regions are increasingly adopting sustainable practices as a way to attract international buyers and access premium markets. Countries like India and Bangladesh are exploring DNA technology to enhance their competitive edge in the global textile market. By certifying compliance

with ethical labor and environmental standards, these countries aim to meet the rising demand for transparency and sustainability from global consumers. The adoption of DNA tech is seen as a critical step for these regions to build trust with international buyers, ensuring that products are not only ethically produced but also meet high sustainability standards. This growing interest from Asian textile hubs reflects the broader global shift toward sustainable fashion and the increasing importance of traceability in gaining access to premium markets.

Hence, combining DNA technology with blockchain to create an immutable record of sustainability claims is important. DNA tagging is increasingly integrated with blockchain for end-to-end supply chain transparency. Provenance, a supply chain transparency provider, uses DNA markers alongside blockchain to authenticate organic wool. Brands like Adidas H&M, Stella McCartney are experimenting with tagged materials that can be reprocessed into new garments. While DNA technologies offer significant opportunities in the textile industry, they also

TABLE 5

Impact of DNA Technologies on Sustainable Fashion Initiatives by Adidas, H&M, Stella McCartney

	<i>Adidas’ Sustainable Apparel Initiative¹⁰</i>	<i>H&M Group’s Traceable Cotton Supply Chain¹¹</i>	<i>Stella McCartney’s Use of Mylo Leather¹²</i>
Objective	Reduce reliance on virgin polyester and ensure recycling in a circular economy.	Address allegations of fraudulent organic cotton sourcing.	Integrate bioengineered, sustainable alternatives into luxury fashion.
Implementation	Used DNA markers to track the origin and lifecycle of materials	Partnered with DNA tagging firms to certify all organic cotton used in their "Conscious" line.	Adopted Bolt Threads’ DNA-engineered Mylo, made from mycelium.
Outcome	Achieved 90% recycled content in select product lines by 2023.	Improved consumer trust and expanded the market share of sustainable products by 15%.	Enhanced brand positioning as a sustainable pioneer.
Economic Impact	Reduced raw material costs by \$1.2 million annually while commanding higher prices for sustainable collections.	Avoided potential losses from reputation damage (~\$10 million) and gained access to premium markets.	Allowed a 25% price premium on new product lines, covering initial costs within the first season.

¹⁰ Sustainable Fashion Market Report: Trends, Forecast and Competitive Analysis to 2030, <https://www.researchandmarkets.com/reports/5988879/sustainable-fashion-market-report-trends>
¹¹ The same place.
¹² Sustainable Fashion Market size, share, trends & competitive analysis by product type (Apparel, footwear, accessories, jewelry, bags) By material (organic cotton, recycled fabrics, hemp, tencel, eco friendly dyes) By end-user; By regions, and industry, forecast, global report 2023-2030. Report: <https://www.futuredatastats.com/sustainable-fashion-market>, <https://www.research-andmarkets.com/reports/5988879/sustainable-fashion-market-report-trends>

TABLE 6

Impact of DNA Technologies on Specific Textile Sectors:
Challenges and Opportunities:

Fast fashion sector	<p>In the fast fashion sector, DNA technologies play a crucial role in driving change by addressing both cost efficiency and ethical expectations. As consumers increasingly demand low-cost options that are ethically sourced, DNA technology provides a solution by assuring the authenticity of materials like cotton and polyester, while maintaining production cost efficiency. This is particularly important in an industry where price sensitivity and ethical sourcing must go hand in hand. DNA tagging ensures that materials are not only genuine but also meet sustainability standards, which appeals to the growing number of eco-conscious consumers.</p> <p>Fast fashion relies on rapid production cycles, and DNA technology supports this by enabling fast verification of materials, allowing for quicker sourcing and production. This ensures that brands can meet their fast-paced delivery timelines without compromising on the quality or authenticity of the materials used. As the industry faces increasing pressure to reduce waste, DNA tagging helps in improving textile recycling and reuse efforts. By making it easier to track the life cycle of materials, DNA technology supports the circularity that is becoming a cornerstone of sustainable fashion practices, ensuring that materials can be efficiently recycled and reused, rather than discarded.</p>
Technical Textiles	<p>Technical textiles include materials for industries such as construction, healthcare, and defense. DNA technologies enable these sectors to improve performance and reliability.</p> <p>Protective Textiles:</p> <p>Fibers embedded with DNA markers can confirm the quality and authenticity of materials used in life-saving applications, such as bulletproof vests or fire-resistant uniforms. Here, economic benefit in ensuring compliance with safety standards, which reduces liability risks and increases market competitiveness.</p> <p>Medical Textiles:</p> <p>DNA-based biopolymers (e.g., spider silk) are being explored for wound dressings and surgical sutures due to their biocompatibility and strength. Researchers are engineering microbes to produce artificial silk for sutures, potentially reducing costs compared to synthetic alternatives.</p>
Home Textiles	<p>The use of DNA technologies in home textiles such as bedding, curtains, and upholstery addresses consumer demand for ethical and sustainable products.</p> <p>Traceable Organic Cotton: DNA tagging can confirm the use of organic cotton in bedding, an essential feature for environmentally conscious consumers.</p> <p>The Economic Impact is, that Brands offering verified sustainable products gain access to niche markets and may charge premium prices. DNA-modified textiles with enhanced properties, such as resistance to bacteria or allergens, have growing demand in health-focused households. For example, antimicrobial fabrics.</p>
Sustainable and Eco-Friendly Textiles	<p>DNA technologies align closely with sustainability goals, especially in eco-friendly textile production. While initial R&D costs are high, these materials often lower long-term production costs by reducing reliance on petroleum-based synthetics. For example, Bolt Threads' Mylo leather offers a sustainable alternative to animal leather, gaining adoption by luxury brands.</p> <p>For example, Synthetic biology enables the creation of biodegradable materials like spider silk and algae-based fibers, which are less polluting than traditional materials. DNA technologies also contribute waste reduction. DNA markers track textile waste recycling, ensuring materials are reused appropriately and meeting circular economy standards.</p>
Luxury or High-End Textiles	<p>Luxury fashion houses are adopting circular production models, using DNA tracking to ensure the authenticity of recycled materials. By integrating DNA-based traceability, brands appeal to eco-conscious and socially responsible consumers while protecting against counterfeit products—a significant issue that costs luxury brands billions annually.</p> <p>DNA markers authenticate high-value materials like cashmere, silk, and leather, offering assurance to discerning customers and enhancing transparency. This allows brands to emphasize traceability for sustainability and exclusivity, reducing revenue loss and strengthening brand equity.</p> <p>Smart textiles further benefit from DNA-modified fabrics with added functionalities like UV protection or temperature regulation. DNA tagging and barcoding have revolutionized the textile supply chain by providing verifiable methods for product authentication.</p> <p>Economic benefits include:</p> <ul style="list-style-type: none">• Counterfeit Prevention: DNA-based tagging ensures product authenticity, reducing economic losses and preserving brand equity.• Supply Chain Transparency: DNA markers enable precise tracing of materials, boosting consumer trust and commanding premium prices for verified sustainable products.

present economic challenges. The initial investment required for integrating DNA tagging systems or establishing bioengineered textile production facilities can be substantial. Additionally, the ongoing costs associated with

the maintenance of DNA-based systems and regular testing contribute to operational expenses. Furthermore, convincing consumers and stakeholders to embrace DNA-verified products necessitates investment in marketing

and educational efforts to build awareness and trust. These factors must be carefully managed to ensure the long-term viability and success of DNA technologies in the market.

The global luxury fashion market is projected to grow from \$70 billion in 2023 to \$120 billion by 2030, with over 30% of luxury goods expected to integrate DNA technology by then. This integration not only supports sustainability goals but also fosters brand loyalty, as consumers are willing to pay a premium for authenticated, sustainable products. DNA technology thus reduces counterfeiting, protects brand value, and aligns with emerging trends like increased transparency, exclusivity, and the shift to circular fashion¹³.The global fast fashion

market is expected to grow significantly, from \$40 billion in 2023 to \$55 billion by 2030. DNA-based traceability is expected to become more prevalent, with over 20% of fast fashion brands integrating DNA technology into their production processes by 2030. This shift is being driven by both consumer demand for transparency and the growing regulatory pressures for sustainability¹⁴.

Economically, DNA technology offers long-term cost efficiency. By reducing waste, improving supply chain efficiency, and ensuring the authenticity of materials, DNA tagging helps fast fashion brands streamline their operations. Furthermore, as more countries implement sustainability regulations for textile products, DNA technology assists brands in complying with these certifications

TABLE 7

Refining the Cost-Benefit Model for Specific Sectors			
Sector	Cost Drivers	Benefit Drivers	Example ROI Metrics
Luxury Textiles	DNA tagging of high-value fibers Integration with blockchain	Premium pricing for authenticated materials Improved customer loyalty	20-30% increase in revenue due to reduced counterfeits
Sustainable Apparel	Biomanufacturing setup Waste management systems	Access to eco-conscious markets Subsidies for sustainability practices	15% cost savings in material sourcing via recycling
Technical Textiles	R&D in bioengineered fibers Testing for safety compliance	Expansion into niche markets (e.g., defense) Reduced liability risks	25% reduction in liability claims due to authenticated protective gear ¹⁵

TABLE 8

Challenges and Opportunities for SMEs	
Challenges	Opportunities
<ul style="list-style-type: none">➤ High Initial Costs: SMEs often struggle with the upfront investment required for DNA technology integration.➤ Limited Technical Expertise: Smaller firms may lack in-house capabilities to manage and implement advanced systems.➤ Supply Chain Complexity: SMEs often operate within larger supply chains, making independent verification challenging.	<ul style="list-style-type: none">➤ Access to Premium Markets: DNA-based certifications enable SMEs to target eco-conscious consumers willing to pay premium prices.➤ Government and NGO Support: Many regions offer grants, subsidies, or collaborations to promote sustainable practices.➤ Partnerships with Large Brands: Collaborating with larger firms that use DNA technologies allows SMEs to integrate affordably into compliant supply chains.

¹³ Luxury Goods Market Size, Share & COVID-19 Impact Analysis, By Product Type (Watches & Jewelry, Perfumes & Cosmetics, Clothing, Bags/Purses, and Others), By End-user (Women and Men), By Distribution Channel (Offline and Online), and Regional Forecast, 2023-2030, <https://www.fortunebusinessinsights.com/luxury-goods-market-103866>

¹⁴ Global Fast Fashion Market to Surpass \$99.84 Billion by 2030 | Exclusive Report by Coherent Market Insights, December 12, 2023, <https://www.globenewswire.com/news-release/2023/12/12/2794957/0/en/Global-Fast-Fashion-Market-to-Surpass-99-84-Billion-by-2030-Exclusive-Report-by-Coherent-Market-Insights.html>

¹⁵ Jensen B., Stoneburner M., Martinez-Pardo C., Wilkinson J., Khodabocus H., Durbiano L., Faist M., Frehland S., Meister P., Vargas-Gonzalez M., Sustainable Raw Materials Will Drive Profitability for Fashion and Apparel Brands, OCTOBER 25,2023, <https://www.researchandmarkets.com/reports/5988879/sustainable-fashion-market-report-trends>

at a low cost, reducing the risk of penalties and boosting brand reputation.

Practical implementation of DNA tagging for SMEs begins with identifying priority areas within their operations. It is essential to focus on high-impact zones where the technology can deliver the most value. For example, SMEs can start by implementing DNA tagging for natural fibers like organic cotton or wool to meet certification requirements. From there, they can expand the use of DNA markers for authenticity in high-value products such as silk or cashmere. This phased approach ensures that the business addresses key product categories first, paving the way for broader adoption. Starting small and scaling gradually is crucial for minimizing risk and managing costs. SMEs can test DNA tagging on a limited product line, such as their most popular or high-demand items, before expanding to other products. This approach

allows businesses to gauge the effectiveness and return on investment before making larger commitments. Additionally, partnering with certified labs for initial testing can reduce the need for costly in-house infrastructure, helping SMEs keep their costs down during the early stages of adoption. Seeking funding opportunities is another important strategy. SMEs should look for grants and subsidies to help offset the costs of implementing DNA tagging. Regions like the EU, for instance, offer grants under programs such as Horizon Europe, specifically for SMEs adopting sustainable technologies. NGOs also often provide financial support for certification costs, especially for fair-trade or organic textiles. By tapping into these funding sources, SMEs can make the adoption of DNA tagging more affordable and accelerate their transition toward sustainable and transparent practices.

TABLE 9

	European Union (EU)	United States	Asia-Pacific (India)	Africa	Private and NGO-Based Support
Program	Horizon Europe – Green Deal Call	Small Business Innovation Research (SBIR)	Technology Development Board (TDB)	Africa Enterprise Challenge Fund (AECF)	Textile Exchange – Corporate Partner Program
Objective	Supports SMEs innovating in sustainability, including sustainable textiles and traceability solutions.	Provides funding for technology-driven SMEs, including those in textiles.	Promotes eco-friendly technologies in the textile sector.	Funds SMEs adopting innovative technologies in agriculture and textiles.	Provides financial and technical assistance to SMEs integrating DNA technologies to ensure sustainable material sourcing. Offers mentorship and marketing support for certified brands. https://textileexchange.org
Funding	Grants of up to €2 million for R&D and implementation.	Phase I offers up to \$150,000; Phase II extends up to \$1 million.	Offers soft loans covering up to 50% of project costs for adopting DNA technologies.	Grants and loans ranging from \$100,000 to \$1.5 million.	Fashion for Good Innovation Fund
Focus Areas	Submit proposals detailing how DNA technologies enhance sustainability in supply chains.	Sustainable manufacturing, innovative materials, and traceability.	Eligibility: SMEs focusing on organic or recycled textiles.	Sustainable fibers like organic cotton and their traceability.	Supports textile SMEs innovating in circularity and transparency, including DNA-tagging solutions.
How to Apply	Leverage partnerships with EU-based research institutions.	Register with grants.gov and present feasibility studies for DNA technology use.	Submit a proposal detailing the environmental and economic benefits of DNA tech adoption	Propose scalable projects integrating DNA tagging into supply chains.	Offers equity-free funding and connects SMEs with global fashion brands. https://fashionforgood.com
Website	https://horizon-eu.eu	https://www.sbir.gov	https://tdb.gov.in	https://www.aecfafrica.org	

To adopt DNA tagging effectively, SMEs should focus on partnering with technology providers that offer tailored and affordable solutions. Companies like Applied DNA Sciences cater specifically to small and medium businesses, providing shared testing facilities, training, and support. Subscription-based models are particularly advantageous, enabling SMEs to spread costs over time and reduce financial burdens, making the technology more accessible. Exploring funding opportunities and subsidies can further ease the financial challenges of implementation. For example, an SME in India producing organic cotton baby apparel faced difficulties in verifying organic claims and navigating rising competition. By partnering with a local lab offering subsidized DNA tagging, the SME launched a pilot program focused on its best-selling baby blankets. This strategic move helped them build credibility and authenticity in their product line. Integrating DNA technology into marketing efforts proved highly impactful. By adding QR codes to products, consumers could trace the journey of materials, fostering trust and engagement. Transparency became a key selling point, and the SME amplified its message through social media campaigns, showcasing its commitment to sustainability and authenticity.

The results were remarkable. Within the first year, the SME experienced a 30% increase in sales, gained certifications that

attracted international premium retailers, and recovered its initial costs within nine months. Such outcomes illustrate the financial viability and long-term benefits of adopting DNA tagging¹⁶.

Globally, various funding programs, grants, and subsidies support SMEs in implementing DNA technologies. By leveraging these resources, along with strategic partnerships and innovative marketing, SMEs can position themselves as leaders in sustainability and transparency, unlocking access to premium markets and fostering enduring consumer trust.

DNA tagging is revolutionizing the fashion industry by providing verifiable data on product origins, enhancing transparency, and fostering consumer trust. Brands like Patagonia leverage traceability as a core component of their sustainability strategies, offering consumers easy access to product authenticity through tools like QR codes. SMEs adopting DNA technology can differentiate their products, justify premium pricing, and recover costs more quickly. Integration with blockchain further enhances transparency, creating accessible, tamper-proof records.

In circular fashion, DNA-tagged materials boost the appeal of recycled products by ensuring authenticity. DNA tagging is becoming a critical tool for reducing waste, promoting recycling, and building brand loyalty. SMEs can implement circular practices by collaborating with suppliers using DNA-

TABLE 10



Cost Breakdown and Optimization Strategies for SMEs Implementing DNA Technologies

Cost Category ¹⁷	Estimated Cost for SMEs (USD)	Strategies to Reduce Costs
DNA Tagging System Setup ¹⁸	\$10,000 - \$20,000	Opt for shared systems or rent equipment
Testing and Certification	\$5,000 - \$10,000 annually	Collaborate with third-party labs.
Training and Integration ¹⁹	\$2,000 - \$5,000	Access online training programs or workshops.
Operational Costs ²⁰	\$2,000 - \$7,000 annually	Focus on limited product lines initially

¹⁶ Decker E., What's Now And Next In Sustainable Textiles? July 27, 2023 <https://www.textileworld.com/textile-world/features/2023/07/whats-now-and-next-in-sustainable-textiles/>

¹⁷ FMT Team,What are the startup expenses for a mobile DNA service?November 1, 2024 (Read more at: <https://financialmodel-templates.com/blogs/capex/portable-dna-testing-service>

¹⁸ The same place.

¹⁹ Ochoa D, How to Develop Cost-Effective Training: Maximize Impact & Minimize Costs,August 21, 2023,<https://www.thinkific.com/blog/cost-effective-training-and-development-methods/>

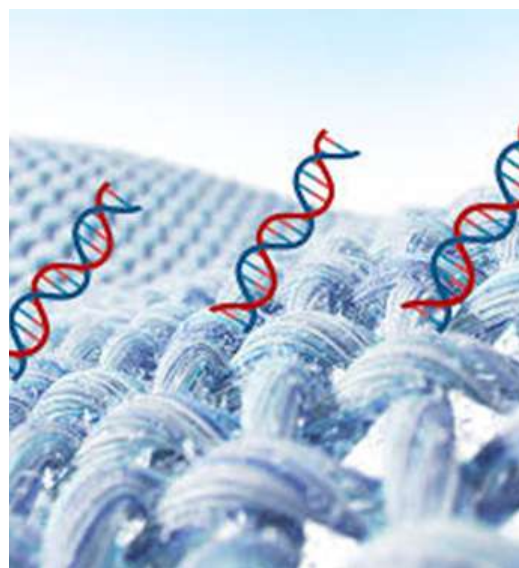
²⁰ The same place.

tagged recycled fibers, tracking materials throughout their lifecycle, and showcasing the recycling journey to eco-conscious consumers. For example, an SME adding DNA markers to recycled denim successfully earned eco-certifications, demonstrating its commitment to sustainability²¹. DNA technology's low entry barriers make it accessible to SMEs, with scalable solutions and collaborative cost-sharing models available. By starting small-tagging select high-demand products-SMEs can gradually expand implementation while building consumer trust. Partnerships with larger companies or technology providers enable access to certifications, reduce initial costs, and enhance credibility. Companies with DNA-backed traceability will be better positioned to mitigate reputational risks, protect revenue, and strengthen long-term brand equity.

Beyond individual businesses, DNA technologies offer long-term benefits for the textile industry. By enabling the tracking of fibers through multiple life cycles, DNA tagging facilitates circular production, reduces dependence on virgin materials, and lowers environmental impacts. It also supports the global standardization of traceability, simplifying international trade and easing compliance in high-value markets like the EU. Precise tracking of carbon and water footprints allows brands to quantify and showcase their sustainability improvements, further boosting competitiveness. The combination of DNA tagging, blockchain, and AI creates fully automated supply chains that reduce costs, fraud, and inefficiencies. These innovations drive demand for sustainable products and open new opportunities in high-skill areas such as testing, software development, and supply chain management.

For SMEs, adopting DNA technology offers a pathway to premium market access, operational efficiency, and consumer trust, enabling them to thrive in an industry increasingly driven by sustainability and transparency.

In conclusion, DNA tagging is a transformative technology for the fashion industry, offering unparalleled transparency, traceability, and sustainability. By ensuring product authenticity and enabling circular practices, it helps businesses reduce waste, enhance operational efficiency, and meet growing consumer demand for ethical products. For SMEs, DNA technology provides an accessible entry point to differentiate products, build brand loyalty, and tap into premium markets. Through scalable solutions, collaborations, and gradual implementation, SMEs can leverage DNA tagging to align with sustainability trends, comply with regulations, and gain certifications that enhance credibility. On a larger scale, DNA tagging promotes global traceability standards, facilitates circular production systems, and supports precise tracking of environmental footprints. Paired with blockchain and AI, it creates efficient, automated supply chains that reduce fraud and improve transparency. As consumer preference for sustainable, traceable products grows and the market for circular fashion expands, DNA technology positions businesses to thrive while driving industry-wide progress in sustainability and innovation.



²¹ BBMG & Recurate, Report: Circular Fashion Is Now, 08.15.22, <https://bbmg.com/recurate-bbmg-circular-fashion-is-now/>

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Թերեզա ՇԱՀՐԻՄԱՆՅԱՆ
«Ամբերդ» հեղափոխական կենտրոնի տնօրենի օգնական, ՀՊՏՀ

ՀՈՒԿԱՆԵՐ ԵՎ ՄՐԱՎՈՐՈՒԹՅՈՒՆ

ԴՆԹ ԵՎ ՏԵՔՍՏԻԼ ԱՐԴՅՈՒՆԱԲԵՐՈՒԹՅՈՒՆ. ՀՈՒՄՔԻ ՀԵՏԱԳԾՈՒՄԻՑ ՄԻՆԶԵՎ ԱՊՐԱՆՔԱՆԻՇԻ ՊԱՇՏՊԱՆՈՒԹՅՈՒՆ: ԻՆՉՊԵՍ Է ԳԵՆԵՏԻԿԱՆ ՓՈԽՈՒՄ ՏԵՔՍՏԻԼԻ ԱՐՏԱԴՐՈՒԹՅՈՒՆԸ

Տեքստիլ արդյունաբերության ԴՆԹ տեխնոլոգիան պահանջում է զգալի նախնական ներդրումներ ենթակառուցվածքների և համակարգերի ինտեգրման մեջ: Այնուամենայնիվ, ներդրումների վերադարձը (ROI) ձեռք է բերվում կեղծիքների նվազեցման ռիսկերի, մատակարարման շղթայի արդյունավետության բարձրացման և պրեմիում շուկաներ մուտք գործելու միջոցով, որոնք առաջնահերթություն են տալիս կայունությանը և էթիկական աղբյուրներին: Փոքր արտադրողները կարող են մարտահրավերների առաջ կանգնել բարձր նախնական ծախսերի պատճառով, սակայն ռազմավարական համագործակցությունը տեխնոլոգիաների մատակարարների հետ կարող է օգնել մեղմել ֆինանսական բեռը և ապահովել աստիճանական ընդունում: ԴՆԹ-ով հավաստագրված մատակարարման շղթաները գրավում են ներդրողներին, որոնք կենտրոնացած են բնապահպանական, սոցիալական և կառավարման (ESG) գործունեության վրա՝ բարձրացնելով շուկայի գրավչության մակարդակը: Հիմնական տնտեսական գործոնները, որոնք պետք է հաշվի առնել, նախնական ներդրումներն են, ROI-ն, ծավալայնությունը և էթիկական արտադրանքի համար հավելվածար վճարելու սպառողների պատրաստակամությունը, որոնց արդյունավետ հավասարակշռումը կարող է ապահովել երկարաժամկետ շահութաբերություն, փոխակերպել շուկայի դիրքավորումը և օգնել ընկերություններին համապատասխանել կայունության կանոնակարգերին՝ էթիկական նորաձևության զարգացող շուկայում հաջողության հասնելու համար: ԴՆԹ պիտակավորման համակարգերը մեծացնում են ապրանքանիշի վստահելիությունը՝ ի վերջո, մեծացնելով նաև վաճառքը և շուկայի մասնաբաժինը բնապահպանական գիտակցություն ունեցող սպառողների շրջանում:

Հիմնաբաներ. ԴՆԹ հարկորոշման համակարգեր, կայուն նորաձևություն, շրջական միջավայր, սոցիալական ոլորտ և կառավարում (օր.), պրեմիում շուկաներ, շրջանաձև նորաձևություն, ապրանքանիշի վստահություն, մասշտաբայնություն, գենետիկորեն ձևափոխված մանրաթելեր, կենսաբայթայվածություն, նյութերի արդյունավետություն, սպառողների պահանջարկ թափանցիկության համար, արտադրանքի նույնականացում

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РЫНКИ И КОНКУРЕНЦИЯ

ДНК И ТЕКСТИЛЬНАЯ ПРОМЫШЛЕННОСТЬ: ОТ ОТСЛЕЖИВАНИЯ СЫРЬЯ ДО ЗАЩИТЫ БРЕНДА. КАК ГЕНЕТИКА МЕНЯЕТ ПРОИЗВОДСТВО ТКАНЕЙ

Внедрение ДНК-технологий в текстильной промышленности требует значительных первоначальных инвестиций в инфраструктуру и системную интеграцию. Однако окупаемость инвестиций (ROI) достигается за счет снижения рисков подделки, повышения эффективности цепочки поставок и доступа к премиальным рынкам, которые отдают приоритет устойчивости и этическому источнику. Небольшие производители могут столкнуться с проблемами из-за высоких первоначальных затрат, но стратегическое партнерство с поставщиками технологий может помочь смягчить финансовое бремя и обеспечить постепенное внедрение. ДНК-сертифицированные цепочки поставок привлекают инвесторов, ориентированных на экологические, социальные и управленческие показатели (ESG), повышая привлекательность рынка. Основные экономические факторы, которые следует учитывать, включают первоначальные инвестиции, ROI, масштабируемость и готовность потребителей платить премию за этичную продукцию. Эффективное уравнивание этих элементов может обеспечить долгосрочную прибыльность, изменить позиционирование на рынке и помочь компаниям соблюдать правила устойчивости, позиционируя их для успеха на развивающемся рынке этической моды. Системы маркировки ДНК повышают доверие к бренду, в конечном итоге увеличивая продажи и долю рынка среди экологически сознательных потребителей.

Ключевые слова: системы ДНК-маркировки, устойчивая мода, окружающая среда, социальная сфера и управление (ESG), премиальные рынки, циркулярная мода, доверие к бренду, масштабность, генетически модифицированные волокна, биоразлагаемость, эффективность материалов, потребительский спрос на прозрачность, идентификация продукта