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Policy brief – Harnessing the potential of blockchain technology for due diligence and sustainability in cotton value chains

Summary

Traceability and transparency in the garment and footwear sector have become a priority for consumers, governments and the industry due to the environmental footprint and social impacts resulting from decades of unsustainable consumption and production practices.

There are huge advantages that can be derived from advancements such as blockchain technology, as they have the potential to build trust and advance due diligence while connecting actors of fragmented and opaque value chains in this industry. Nonetheless, these solutions may be challenging for small-scale actors and vulnerable groups due to the digital gap, implementation costs and required skills. Policymakers and regulators have a role to play in spurring coordinated action to scale up such solutions and to ensure that the digital transformation can support higher sustainability in the industry, leaving no one behind.

This policy brief provides highlights and recommendations emerging from the ongoing implementation of the United Nations Economic Commission for Europe (UNECE) pilot project on a blockchain system for traceability and due diligence in cotton value chains, launched in connection with the UNECE-United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) initiative "Enhancing traceability and transparency of sustainable value chains in the garment and footwear sector".

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I. Introduction

A. Garment and footwear value chain trends and challenges

1. In the garment and footwear industry, companies are being confronted with the rise of the conscientious consumer who questions the social conditions and the environmental footprint of the clothes they buy while calling for greater transparency.[1] Hence, making responsible choices easier for both businesses and consumers is a requirement. Traceability and transparency of value chains and reliable sustainability claims can help facilitate more informed choices. However, the sector is awash with misleading labelling and complex language that makes it difficult for both business and consumers to follow through on their good intentions.

Sustainability risks in cotton value chains

Cotton represents 24 per cent of the fibres market for the apparel industry,[2] which makes it the world's most widely used natural fibre with an approximate yearly global production of 25 million metric tonnes.[3] Worldwide, about 26 million farmers grow cotton in 75 countries, while cotton growing and processing for textiles and apparel provide jobs and incomes to approximately 100 million families.[4] Cotton is a critical source of economic growth. At the same time its impact on climate, water scarcity, water pollution (due to the use and release of hazardous chemicals), and human health and ecosystems, is particularly concerning. Global cotton cultivation is estimated to require 200 thousand tonnes of pesticides and 8 million tonnes of fertilizers per year, some 16 per cent and 4 per cent respectively of the total global use of pesticides and fertilizers, despite cotton accounting for only 2.5 per cent of arable land use.[5] One T-shirt requires around 2,700 litres of water.[6] So cotton clothing production contributes on a massive scale to the depletion and pollution of local water sources.

Cotton cultivation is also associated with high social risks, including injuries, exposure to hazardous substances, low wages, forced and child labour, gender inequality, corruption, and fragility of legal systems.[7] In addition, the volatility of market prices and the uncertainty stemming from current purchasing and subcontracting practices have increased informality and precarity. Cotton production not only affects the health of the textile workers directly, but also that of wider communities because of the environmental pollution it causes; so one major industry challenge is to improve cotton production practices and, very importantly, to link these better practices to the sustainable cotton used by brands, retailers and manufacturers. This makes traceability a central component of many of the current sustainability initiatives in the apparel sector.[8]

2. The garment and footwear industry is a critical sector with global and opaque value chains and high environmental, social and health impacts that have been extensively

[1] Business of Fashion and McKinsey & Company, *The State of Fashion 2020*. Fourth annual State of Fashion report (2019).
[2] United Nation Environment Programme (UNEP*), Sustainability and Circularity in the Textile Value Chain: Global Stocktaking,* Report (Nairobi, Kenya, 2020).
[3] Source: International Cotton Advisory Committee (ICAC), 2018 from the WTO World Cotton Day (7 October 2019) flyer. Available at https://www.wto.org/english/tratop_e/agric_e/cottonday2019_e.pdf (accessed 6 April 2021).
[4] Ibid.
[5] Ellen MacArthur Foundation, "New Textile Economy: Redesigning Fashion Future", (28 November 2017). Available at https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future.
[6] Textile Exchange, *2025 Sustainable Cotton Challenge: First Annual Report 2018*.
[7] UNEP, *Sustainability and Circularity in the Textile Value Chain.*
[8] Ibid.

documented.[9] The global fragmentation of production is another challenge which is further complicated by the prevalence of subcontracting and informal work, especially in the upstream segment of the value chain. In fact, abuse and exploitation of workers, many of whom are women, is a major challenge in a sector where in certain countries wages are lower than the minimum wage, which is well below a living wage.[10]

3. The impact of the industry on the environment is also concerning, being a resource-intensive sector, and the fourth highest pressure category in the European Union in terms of use of primary raw materials and water,[11] accounting for more carbon emissions than those of all international flights and maritime shipping combined.[12] Most companies do not have full visibility and control over their value chain. Today only 34 per cent have started putting traceability systems in place, but for the most part these only extend to their immediate suppliers,[13] while human and labour rights violations and environmental impacts are often happening further away from consumers' markets.

B. The potential of blockchain technology

4. Innovation and advanced technologies can turn challenges into new opportunities by boosting information exchange to achieve interoperable traceability systems and to connect value chain actors, thus fostering transparency, sustainable business models and lifestyles. The 4.0 technologies[14] (e.g. the internet of things, artificial intelligence, and distributed ledger technologies like blockchain) support policy approaches to scale up innovative solutions and partnerships for a circular, climate neutral and inclusive industry by 2030, as set by the United Nations Sustainable Development Goals (SDGs), and particularly SDG 12 on responsible consumption and production.

5. For instance, no longer just for cryptocurrencies, blockchains have a myriad of possible applications.[15] Their ability to consolidate detailed and specific ledger information allows for verifiable tracking and tracing of any product from its origins through every stage of production and shipment to its journey's end (the point of purchase). Blockchain technology is a type of distributed ledger technology (DLT). It is a distributed (decentralized), verified, trusted, secure transaction ledger, which can record data that allows for the verification of information. Most importantly, the blockchain records data in an immutable way, thereby making the information more easily distributed for verification and disclosure purposes. In garment and footwear value chains this could include, among others, data about raw material harvest, production, product use, end of life disposal, sustainability certifications and vendor contracts. Hence, blockchain technology boosts information exchange and provides immutable data storage, which fits the needs of such a fragmented industry.

6. A blockchain system records transactions on a ledger (an immutable distributed database) held by peers in a network. These transactions can be readily checked and are equally accessible to all parties if they are recorded on a public blockchain, or to all parties

[9] Some recent examples include the Global Fashion Agenda and the Boston Consulting Group, *Pulse of the Fashion Industry*. 2018 Report (2018); and the United Nation Environment Programme (UNEP*), Sustainability and Circularity in the Textile Value Chain: Global Stocktaking,* Report (Nairobi, Kenya, 2020).

[10] ILO, *Tripartite Declaration on Principles concerning Multinational Enterprises and Social Policy, fifth edition*, (Geneva, March 2017).

[11] European Environment Agency, *Textiles in Europe's Circular Economy*, Briefing no. 10/2019 (19 November 2019).

[12] Ellen MacArthur Foundation, "New Textile Economy".

[13] UNECE, "Background Note Blockchain for Due Diligence in the Garment and Footwear Sector", (2019), available at https://unece.org/sites/default/files/2021-03/2019_Paris_Blockchain-UNECE-OECD_background_note.pdf.

[14] World Economic Forum (2016) Available at: https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab/.

[15] Throughout this document, the terms "blockchain" and "blockchain technology" are used because they are the most known terms, but they can be considered to be synonymous with "distributed ledger technology (DLT)".

who have permission to "read" them on a private/permissioned blockchain. Cybersecurity is managed by using separate public and private "keys" for cryptographically signing and accepting transactions, and by using consensus mechanisms for validating transactions. These mechanisms require a majority consensus among all nodes that have copies of the blockchain database (which may be thousands of nodes) and often combine cryptographic algorithms with systems of rewards and penalties that make cheating prohibitively expensive.

7. Blockchain networks provide an opportunity to increase traceability and, accordingly, sustainability in value chains through the creation of a highly trustworthy common source of verifiable knowledge about transactions that is accessible to all stakeholders regardless of their location, as long as they have access to the Internet (the technology used for communicating with blockchain networks). This common, trustworthy source of knowledge can then be used by application developers to create a system that stakeholders can use to identify and address sustainability risks and impacts along the value chain.

8. As an example, a well-designed blockchain-based application can allow brands and retailers to access the blockchain (via a user interface program) to verify the origin of each input used in the manufacturing process. In the future, industry regulators will be able to check the data stored on such systems in order to examine a product's entire lifecycle process using a blockchain's digital ledger. This will allow them to verify, for example, inspections made by competent authorities to identify occupational health and safety violations, human rights breaches such as the use of forced labour, or unauthorized subcontracting. Likewise, consumers will be able to use QR codes or apps to view a product's full journey and its certification from field to shelf. Accordingly, they will be able to make an informed decision before purchasing a product.

II. Highlights – UNECE blockchain pilot in the cotton value chain

9. In January 2020, UNECE launched a pilot project to develop a blockchain system for traceability and due diligence in the cotton value chain, from field to shelf. The pilot is connected to the UNECE-UN/CEFACT wider initiative called "Enhancing Traceability and Transparency for Sustainable Value Chains in the Garment and Footwear Sector" jointly implemented with the International Trade Centre (ITC) and with financial support of the European Union.[16] The initiative aims to provide governments and companies with a set of tools to advance traceability, transparency and sustainability in this industry (a policy recommendation, a call to action, a standard for information exchange, implementation guidelines and blockchain pilot projects).

10. Hence, the purpose of this first pilot is to test the UNECE-UN/CEFACT traceability and transparency toolbox in a blockchain environment. These tools support the identification and coding of the key data entities that need to be collected and exchanged at critical data points in order to assess the sustainability performance of products, processes and facilities. One of the expected outcomes of this pilot is to demonstrate the feasibility of end-to-end traceability of cotton-based products, from farm to consumer, using blockchain technology to increase the trustworthiness of the data as well as the connectivity, cost-efficiency, scalability and transferability of the solution. Another goal of the pilot is to assess the capacity of companies to make risk-informed decisions while using the UNECE-UN/CEFACT traceability and transparency approach and standards in a blockchain environment. The pilot is being implemented in collaboration with industry actors, such as brands, cotton cooperatives, certification bodies and garment manufacturers covering the entire spectrum of value chain processes from field to shelf in countries like Egypt, Germany, Italy, Switzerland, the United Kingdom and the United States.

11. The UNECE cotton blockchain pilot aims to test a selected set of sustainability claims, identified jointly with partners. Partners have also been asked to do the following:

[16] The project website and key documents are available at: https://unece.org/trade/traceability-sustainable-garment-and-footwear.

- Identify those products and materials (traceable assets) to which one or more of the selected sustainability claims should be applied.
- Collect and exchange relevant information and documents with business partners to achieve digital traceability.

12. In fact, for a sustainability claim to be robust and valid, it must be supported by business information and documents (e.g. shipping documents, delivery notes, invoices) and sustainability certificates that are collected at relevant nodes of the value chain. As a complement to the digital traceability, the physical traceability (connection between the physical and digital traceable assets) can be ensured by markers, such as DNA markers.[17] These physical markers help to ensure the authenticity of the digital data by providing a common identifier. For example, if an auditor has a trustworthy electronic certificate for organic cotton that has a DNA marker, and the auditor examines the physical cotton and finds that it has the DNA marker, then he knows that the certificate is valid for that cotton and no one has substituted or mixed it with cheaper non-organic cotton. Physical traceability adds an additional layer of trustworthiness to digital traceability and thus supports overall risk mitigation, claims enforcement and quality control.

A. Implementation progress

13. Since its launch in January 2020, with the contribution of the engaged partners and the guidance of the experts of the multi-stakeholder policy platform set by the UNECE initiative, the cotton blockchain pilot has substantially advanced.

1. Scope and targets

14. A first *stocktaking exercise* (January to March 2020) was undertaken to avoid duplication by identifying blockchain projects with similar purposes[18] and document existing best practices and lessons learned. The scope of the pilot was then defined based on the result of a detailed questionnaire completed by project experts and key industry actors, which also supported the development of the business and technical requirements for the procurement of the blockchain solution.

15. Project experts agreed on several key targets for this first pilot:

- End-to-end traceability in line with relevant norms and standards for sustainability
- A scalable pilot that could eventually be used across the entire textile sector and for any kind of sustainability claim
- A multi-claim solution, able to validate a wide range of sustainability claims (social, health and safety, environmental, animal welfare related) for specific supply chain partners, but also for the entire value chain
- A stand-alone pilot, able to function independently and without a link to other projects or software
- Technological effectiveness and reliability
- A good understanding of the modelling required to build a blockchain application
- A good understanding of on-the-ground operating environments and constraints
- Clear identification of data collection points within the supply chain

[17] The multi-stakeholder initiative Fashion for Good, C&A Foundation and the Organic Cotton Accelerator "Tracing Organic Cotton from Farm to Consumer": https://fashionforgood.com/wp-content/uploads/2019/12/Fashion-for-Good-Organic-Cotton-Traceability-Pilot-Report.pdf.

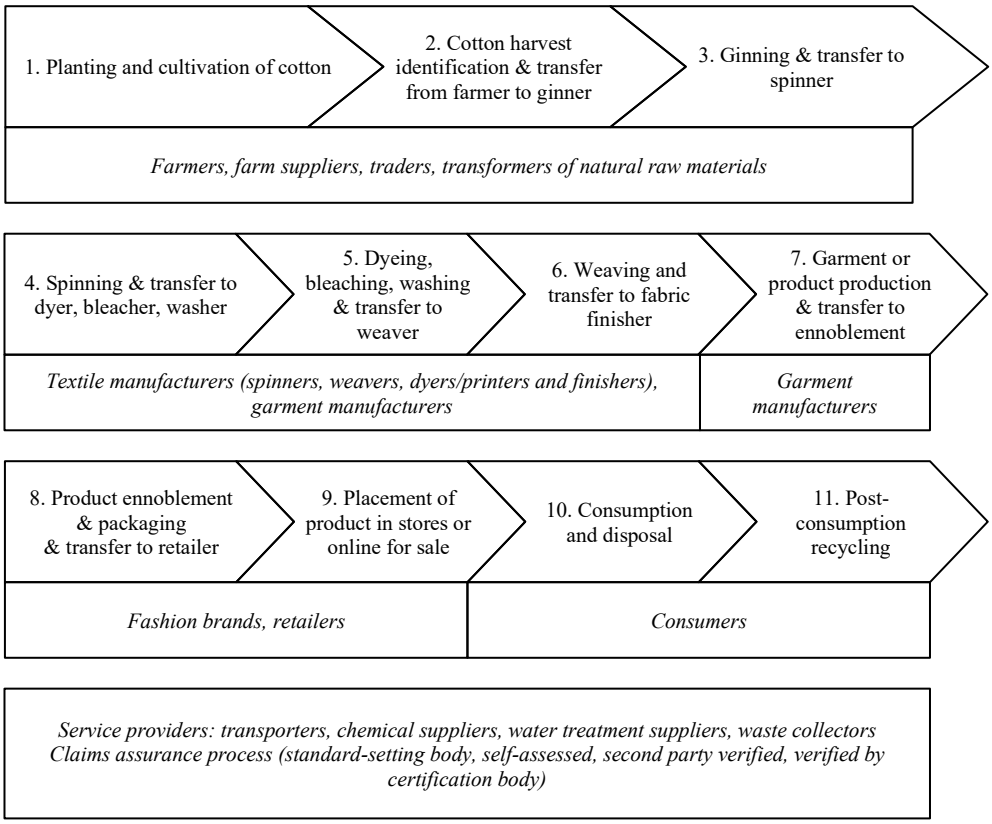
[18] Similar projects include the following: UNIDO "Egyptian Cotton Project"; UNDP "Sustainable Cashmere Traceability"; Haelixa "Tracing Organic Cotton from Farm to Consumer"; Avery Dennison "Trace Blockchain for Apparel & Footwear Transparency &Traceability"; Italian Ministry of Economic Development/IBM "Blockchain for Made in Italy Traceability: Origin, Quality, Sustainability".

- Testing of various scenarios and hypotheses during the roll out

2. Implemented activities

16. Thereafter a *business process analysis* was carried out (April to May 2020) and shared with key industry actors and pilot partners to develop a standardized methodology for identifying the minimum set of data elements to be collected and exchanged to achieve traceability and transparency in all main stages of the cotton value chain—from cotton cultivation, though manufacturing and retailing on the business to business (B2B) level, to consumption and post consumption (see figure 1).

Figure 1
Standard cotton value chain (business process analysis)



17. As part of the business process analysis, 72 *user stories* were drafted (June to September 2020) in collaboration with pilot project partners to define users' needs for traceability and transparency information about selected products and materials. On this basis, a list of focus areas for the key *sustainability claims* (see table 1) was developed, in line with the guidelines in UNECE Recommendation No. 46,[19] for the formulation of claims and their main components (i.e. objective, requirements, traceable asset and verification criteria).

18. Then a pilot *"red thread" document* (October 2020) was developed to describe the pilot storyline for the actors involved and their roles and activities at the various stages of the cotton value chain, as shown in figure 1. The document includes the user stories and identifies relevant information and supporting documents (business documents, certificates, inspection reports) to be collected at each data point to enable traceability and transparency, in line with the business process analysis.

[19] UNECE, *Recommendation No. 46: Enhancing Traceability and Transparency of Sustainable Value Chains in the Garment and Footwear Sector* (ECE/TRADE/C/CEFACT/2021/10) (April 2020). Available at: https://unece.org/sites/default/files/2021-02/ECE_TRADE_C_CEFACT_2021_10E_Rec46-Textile.pdf.

Table 1
Focus of sustainability claims for the UNECE cotton blockchain pilot

Sustainability claim	*Focus area*
A high-level statement about a characteristic of a product or about a process or an organization associated with that product and material (traceable asset)	Origin of materials and products
	Fibre content, including organic and recycled fibres
	Use of chemicals
	Product quality
	Social/environmental performance of products, processes and facilities, based on the minimum set of sustainability criteria[20]

19. The development of the *partners' use cases* (November to December 2020) to achieve digital traceability in the blockchain-based solution was carried out through three steps:

(a) **Identification of claims and traceable asset**: The expert team provided guidance[21] on the definition of claims, criteria and content, which enabled the pilot partners to choose their sustainability claims and identify the material and/or products to trace.

(b) **Data collection**: Once the claims and product/material value chains were selected, the expert team provided the partners with a template with the data needed for each business process of the value chain. The partners had to fill it in with relevant data to support their claims, possibly involving their suppliers, in order to cover the whole value chain (to the extent possible). In accordance with the assurance models identified within the pilot (e.g. self-declared, self-assessed, second-party verified, third-party verified), the partners provided different types of documents to substantiate their claims (e.g. certifications, inspection/audit and reports, shipping documents, invoices).

(c) **Data analysis and data sharing**: The data shared with the secretariat, expert team and the technology-solution provider was analysed from a business and a legal perspective. The purpose of such an analysis is to guarantee the confidentiality and privacy of data, while also defining the level of supply chain visibility of the data.

20. From a *legal standpoint*, work was undertaken (February to March 2021) to identify the following aspects impacting the development and implementation of the blockchain-based solution:

- Governing law and jurisdiction
- The governance framework for an open-source software solution
- Intellectual property rights
- Liability
- Data protection and data privacy (e.g. EU GDPR[22] and other laws concerning data privacy)

21. To avoid legal uncertainty, a common set of rules is in the process of being designed and approved by all the parties involved, considering the above legal aspects.

22. This methodology has supported the development of the blockchain-based solution and infrastructure. The development of the blockchain system was undertaken through the joint efforts of the pilot project's partners, the expert team and the technology-solution provider with the goal of ensuring that the developed solution meets the business

[20] Minimum criteria are identified in UNECE Recommendation 46, and aligned with the OECD Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector, and the set of sustainability standards included in the ITC Sustainability Map.
[21] See UNECE Recommendation No. 46, Part II, Section C.1: Sustainability Claims.
[22] European Union (EU) General Data Protection Regulation (GDPR) 2016/679 (2016). Available at: https://eur-lex.europa.eu/eli/reg/2016/679/oj.

requirements and the needs of the industry to enable traceability and due diligence in the cotton value chain.

23. Testing of the blockchain-based solution with the users (pilot partners) started in March 2021.

3. System features and functionalities to date

24. The project's experts and industry actors have emphasized the importance of taking the following features and functionalities into consideration when developing the blockchain-based solution:

- The granularity of traceability (i.e. how many data points should be established for collecting information along the value chain)
- Flexible arrangements for uploading (e.g. audit reports, certificates, questionnaires, etc.)
- Differentiated sustainability layers (product, process, facility levels)
- Separation in time, processing and access of the traceability layer from the certification layer
- The relationship between a product's fibre integrity and traceability (e.g. a yarn, finished fabric, garment item)
- Access to data based on pre-defined parameters
- Adequate scalability and flexibility of the solution to allow its eventual implementation on a large, mass-market scale.

25. The *procurement of the solution* (June-September 2020) was undertaken through a request for quotations on the United Nations Global Marketplace (UNGM), with the technical and commercial evaluation led by the United Nations Office in Geneva (UNOG). The selected vendor is SUPSI—the University of Applied Sciences and Arts of Italian Switzerland.

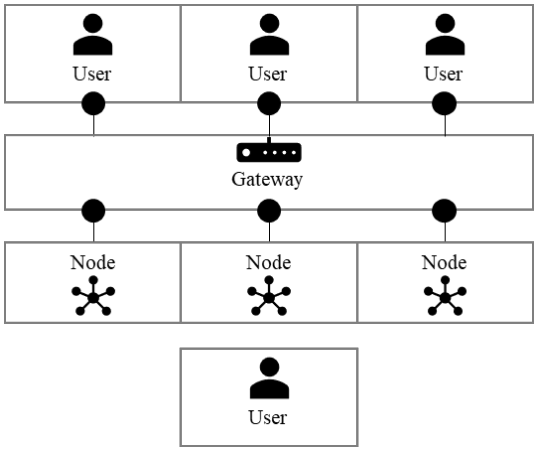
26. To encourage the greatest possible uptake, the blockchain system developed with the pilot (October 2020 – March 2021) features a *hybrid solution* that includes various additional technologies (e.g. cloud-based storage) and is implemented on a public permissionless blockchain. This does not exclude future versions from using private, permissioned blockchains which allow for specific interoperability, privacy and restricted access (it is sometimes easier to clearly define who can see what on a permissioned blockchain).

27. The solution that has been developed is an *Ethereum blockchain,* which allows for the running of smart contracts and can be easily adapted to any extension from the original version. The pilot project application is designed to run in both a web version and smartphone/tablet application to expand its accessibility to all partners in the value chain. Initially, users will perform manual data entry. Later, the transfer of data from existing systems will be allowed through an application programming interface (API), and options are being developed for tailoring the solution to the needs of SMEs.

28. The pilot system has been developed in open-source code/programs where the intellectual property rights allow public use. This approach has been necessary to guarantee the full transparency of the work and software tools developed under the project.

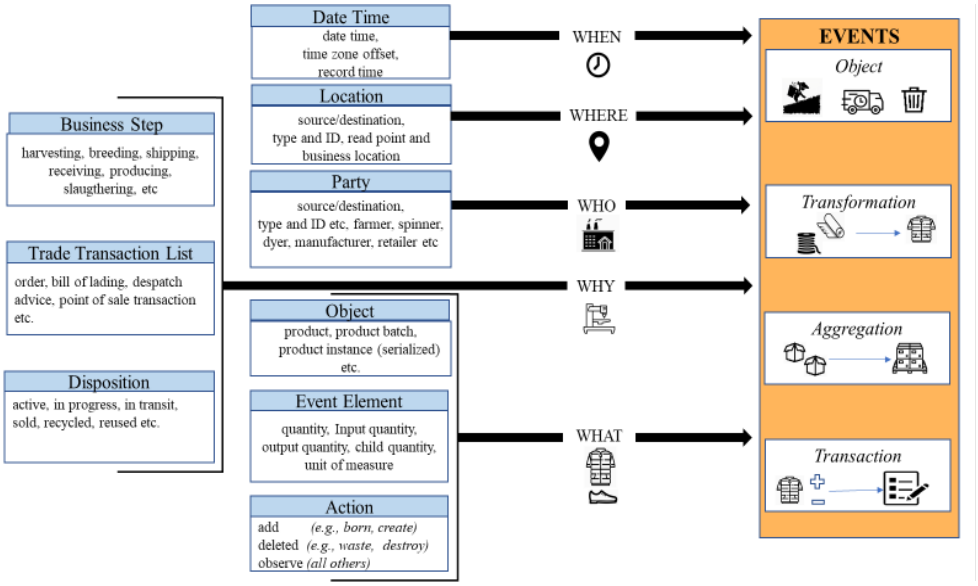
29. Together with the use of a public permissionless blockchain, open-source programs will ensure companies in developed, developing and transition economies have full access to the technology developed under the pilot project. In the future, the business model needs to be evaluated and considered to allow for possible API integrations, which would lead to architectures based on two different blockchain layers with an interoperability interchain protocol.

Figure 2
Simplified representation of the blockchain-based solution for distributed access



30. The blockchain platform is designed to guarantee the *data confidentiality* in compliance with applicable regulations such as the EU GDPR. The overall application will implement several levels of transparency and supply chain visibility (i.e. privacy/confidentiality by design, on-chain and off-chain data and transactions). For this pilot, the data set has been minimized for a lean approach when exchanging data and complying with the most important data regulation. This approach also helps keep the cost of the blockchain-based solution low.

Figure 3
Examples of "5Ws" information collected by value chain partners



31. The traceability data collected from value chain partners, from cotton cultivation to retailing is aligned with the ISO 19987 (EPCIS) standard[23] and is based on the so-called "5Ws": who, what, where, why (how), when[24] model, as illustrated in figure 3. More detailed explanations can be found in UNECE Recommendation No. 46 and its guidelines as well as in Part 2 of the Business Requirements Specification[25] developed under the project.

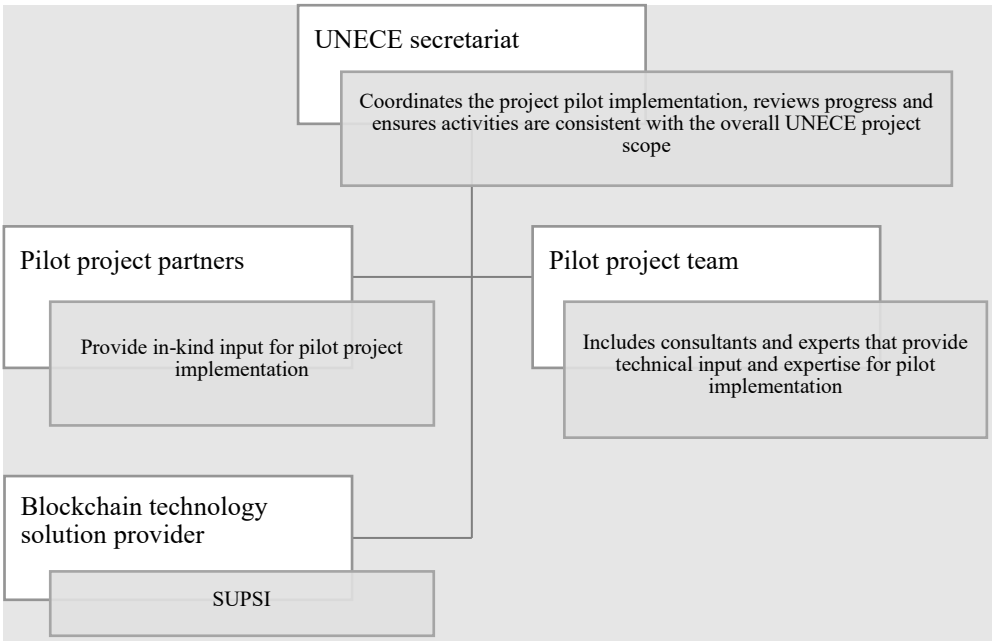
[23] ISO/IEC 19987:2017 defines Version 1.2 of Electronic Product Code Information Services (EPCIS). The goal of EPCIS is to enable disparate applications to create and share visibility event data, both within and across enterprises. Available at https://www.iso.org/standard/72926.html.
[24] See UNECE Recommendation No.46, Part II: Guidelines, Section C.6: Events.
[25] UN/CEFACT, "Business Requirements Specification for Traceability and Transparency in the Textile and Leather Sector, Part 2: Use Cases and CCBDA Data Structures" (February 2021).

4. Management and governance

32. The pilot is led and coordinated by the UNECE (see figure 4) secretariat based upon three layers of work:

- The strategical layer (project team and experts)
- The services layer (technology solution provider, auditing, standard-setting bodies, legal support, product tracking, academia, training)
- The operational layer (implementing partners, i.e. transformers of raw materials, suppliers, manufacturers, brands)

Figure 4
The pilot project governance



III. Lessons learned on gaps and challenges

33. *Any work on new solutions should involve the development of instruments for the exchange of information, supporting documents and certificates/inspection reports at key data points along the entire value chain.* In fact, one of the key issues for traceability and transparency is that existing databases are fragmented and therefore cannot provide a single picture of a product's provenance and processing. The most prevalent practice in the industry is to manage supply chain operations, product sales and purchasing-related data through a web of solutions such as enterprise resource planning (ERP) packages, traditional databases and server applications—with company keeping its own, separate, "solution web". In addition, most of the data collected across these solution webs refers to immediate suppliers and purchasers, with no information about the suppliers of a supplier or the clients of a buyer. As a result, these solutions have led to partial and unreliable data scattered among numerous parties. Moreover, the quality of data can be degraded when it is exchanged between stakeholders due to the lack of a standardized technological infrastructure (i.e. the data is subject to reinterpretation, manual reformatting or re-entry, lost data when transferred data contains information that is not collected by the destination system, misinterpretation due to differences in codes, and a host of other issues).

34. *To effectively coordinate the collection of relevant information and supporting documents throughout the value chain and achieve the digital end-to-end traceability, all*

Available at https://unece.org/sites/default/files/2021-03/BRS%20Traceability%20and%20Transparency%20in%20Textile%20and%20Leather%20Part%20II-UC_CCBDA%20v1.0.pdf.

value chain actors need to commit and allocate the necessary financial, human and technical resources. Due diligence requires that partners implement (i.e. invest in) certification, inspections and audits related to sustainability performance and share this information—but some may be reluctant to do this. In addition, the implementation of blockchain-based solutions requires investment in training and capacity-building activities for users. In terms of costs, digital traceability requires an investment in technology (software, hardware, process improvement), eventually complemented by physical markers (e.g. DNA markers), which account for an additional cost.

35. *Such solutions may be challenging for SMEs, small-scale actors and vulnerable groups due to the digital gap, implementation costs and the required skills.* In an industry that is globally fragmented, and where small and medium-sized enterprises (SMEs) account for more than half of the industry, full accessibility needs to be granted to these actors through skills development programs, training and effective cost-distribution schemes, including on compliance with sustainability schemes and criteria. To address these concerns, implementations need to include making low-cost devices and user-friendly data collection tools available to ensure that smaller actors (at the farm and factory levels) in producing countries can provide the required information. To have efficient and effective tools, their content and design should take into consideration the language of users, communication channels, technology access (i.e. to electricity and the Internet) and other local implementation conditions. This will build the confidence needed to support widespread use.

36. *Nonetheless, several benefits stand out from the implementation a blockchain-based solution to support the attainment of traceability and due diligence for consumers, businesses, regulators and investors.* Blockchains offer immutable and trustworthy data storage with distributed access available to all implementing partners. This can ensure trustworthy digital archiving in complex value chains, reduce the need for auditing, and facilitate documents sharing which can lead to enhanced cost efficiency. Interoperability with existing business data management systems using UN/CEFACT standards for information exchange, and implementation of UNECE Recommendation No. 46 and its guidelines for a traceability and transparency framework can also contribute. Additionally, traceability can create the visibility and transparency that consumers, investors, and financial operators need to make purchasing and investment decisions that have a sustainable impact and which support green finance (see table 2).

Table 2
Benefits of a blockchain-based solution in support of traceability and due diligence

Stakeholders	*Benefits*
Consumers	• Increased trust in sustainability claims for products and materials
Businesses	• Cost efficiency led by digital archiving, reduced auditing, facilitated documents sharing
	• Enhanced trust and communication with business partners and customers
	• Immutable and trustworthy data storage with distributed access
	• Interoperability with existing data management systems (based on APIs)
Investors, financial operators	• Enhanced visibility and accountability for impact investment decisions
Regulators	• Improved visibility/access to reliable information on compliance with policy and regulatory requirements for sustainability and due diligence

IV. Preliminary considerations and recommendations on the way forward

37. The following preliminary general considerations and recommendations are emerging from the ongoing implementation of the cotton blockchain pilot and will be finalized upon its completion:

38. **Commitment and collaboration of all the stakeholders in the value chain is a requirement:** Value chain traceability allows companies to follow material and production flows from raw material extraction and production until the final product reaches the end user, and beyond in the post-consumption phase. It is critical for legal compliance and due diligence. Nonetheless, implementation is a complex issue because it requires the collaboration of all the actors involved in the value chain and the deployment of common and reliable technical solutions in widely different environments.

39. **The benefits of digital technology can outweigh the costs:** Although digital technology requires a significant investment, the benefits of establishing greater levels of traceability and transparency can outweigh costs. In fact, blockchain solutions can help consumers make ethical choices, investors fund responsible businesses, regulators advance due diligence, and companies better manage reputational risk, realize efficiencies, build stronger relationships with their suppliers base, and be more resilient in case of disruptions as they will be able to trace the status of goods across their entire supply chain network.

40. **Ensuring interoperability with other evolving technologies is key:** Blockchain solutions must be able to exchange data and interact with other evolving technologies such as artificial intelligence (AI), machine learning, the Internet of Things (IoT) and other digital identity systems in order to keep abreast with the benefits provided by these digital developments.

41. **Open source, inclusive solutions and building capacity is essential for scaling up:** Policymakers and regulators have a role to play in spurring coordinated action, scaling up innovative and open solutions and building capacity and inclusive partnerships to ensure that the digital transformation can support higher sustainability in the industry at global scale while leaving no one behind. In particular, they should do the following:

- Create the necessary ecosystem for engaging all stakeholders and ensure that the blockchain technology can effectively enhance market access for small actors and vulnerable groups.
- Devise tailored policies and regulations to support competition and facilitate the connection to other key technological developments such as AI, IoT, big data and cloud computing.
- Develop in a concerted manner the necessary supporting frameworks for data security, privacy and governance as preconditions for accelerating adoption.
- Adopt a standardized data model for inspection reports/certificates, credentials and distributed identity management based on international standards for information exchange such as the UN/CEFACT e-business standards.
- Set up the right infrastructure to help build applications in a cost-effective and interoperable manner.
- Support investment in the related education for entrepreneurs, civil servants and the general public.