Sourcing of post-industrial cotton textile waste in the Tangier area, Morocco

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IN PARTNERSHIP WITH

AMITH

Kingdom of the Netherlands

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List of Acronyms

AMITH	Moroccan Association of Textile and Clothing Industries
DNA	Deoxyribonucleic acid
IFC	International Finance Corporation
TFZ	Tangier Free Zone
UNIDO	United Nations Industrial Development Organization

1. Introduction

1.1 MOROCCAN TEXTILE SECTOR OVERVIEW

The textile industry is a strategic sector for the industrial development of Morocco. It employs more than 200 000 people, accounting for more than a quarter of all industrial jobs.[1] Morocco has more than 1,500 textile companies that supply major players.[2] The Spanish company Inditex is the largest purchaser, contracting with more than 300 small factories in the Tangier area. The most important textile regions in Morocco are Casablanca-Settat, Tanger-Tetouan-Al Hoceima, and Fès-Meknès.

In 2020, the sector generated 50.4 billion Moroccan dirhams in revenue and 36.5 billion dirhams in exports,[3] with Europe being the main export market (mainly France, Spain, and the United Kingdom). According to the Moroccan Association of Textile and Clothing Industries (AMITH), Morocco is the seventh-largest supplier of clothing to Europe.

AMITH represents most textile and apparel companies in Morocco, with actors along the value chain including producers, collectors, and recyclers. It promotes the sector's quality, productivity, and competitiveness. Another major actor in the sector is the School of Textile Industries and Clothing, which provides engineering degrees focused on the sector and has a developed research and development department. The Cluster of Moroccan Textile Techniques was founded in November 2013 to support the growth of Moroccan companies in technical textiles and to stimulate innovative and collaborative projects. The Moroccan Technical Textile Cluster and the Centre des Techniques et Matériaux de Construction have recently collaborated in using textile waste in the construction industry. Other key partners of the sector are the Moroccan Denim and Fashion Cluster, the Casablanca Home Textile Cluster, the Technical Center for Textiles and Apparel, and the Casa Moda Academy (a training center for designers).

Morocco is hoping to turn its textile industry into a global market leader by 2035 by adopting a new strategy, called "Dayem Morocco," which will adopt eco-friendly habits, including recycling and reuse of waste. This strategy is focused on maintaining, consolidating, diversifying, and conquering new markets such as North America and northern Europe. Morocco also created the Industrial Acceleration Plan 2014-2020, allocating 3 billion dirhams per year for 2014 to 2020 to individual companies working along the textile value chain via the Industrial Development Fund. The plan is designed to enable textile companies to modernize, develop, and internationalize. A new plan for the period 2021-2035with a new vision that is aligned with the national New Development Model

The EU Carbon Border Adjustment Mechanism (or carbon tax), expected to enter in full force in 2027, should impose new environmental standards on companies exporting to the European Union, which directly affects textiles, especially those produced in a non sustainable manner that generate a large carbon footprint.

1 Ministry of Industry and Trade
2 https://www.lavieeco.com/economie/textile-des-transformations-tres-encourageantes/
3 https://www.cfcim.org/wp-content/uploads/2021/09/1039-septembre-2021-Textile.pdf

1.2 TEXTILE WASTE

According to a United Nations Industrial Development Organization (UNIDO) study that quantified textile waste in Morocco, 70 percent to 80 percent of the entire Moroccan and clothing industry and thus approximately 77 percent of textile waste is concentrated in the areas around Casablanca (42 percent) and Tangier (35 percent) out of an estimated total 83,200 tons of textile waste in Morocco per year, of which 16,700 tons is reusable and 66,500 tons is recyclable. Fabric cutting during confection generates the most waste within the value chain.

The International Finance Corporation (IFC) is attempting to steer the Moroccan textile and clothing industry toward circularity to support development of a value chain for recycling and valorization of pre-consumption textile waste by assessing the potential to recycle and use pre-consumption textile waste, particularly in the area around Tangier. This is usually waste generated during the production process, such as cutting waste, dead stock, and nonconforming products, which could be reused and recycled. The objective is to support the sustainability of the clothing and textile industry by encouraging adoption of circular economic models, restoring value, reducing waste, and increasing access to markets.

The Moroccan textile sector aims to adopt circular production models, thus benefiting from the country's world-class infrastructure, particularly its ports, and its proximity to the European market. Morocco can create a greener, more sustainable textile industry that can meet the demands of increasingly environmentally conscious consumers. It can position itself in the circular textile industry segment, triple its textile production, create jobs, and explore new markets.

Increasing the sustainability of the textile sector requires using renewable energy sources and adopting environmentally friendly manufacturing and dyeing methods. A circular production model allows the use of inputs to be reduced and eliminates waste. Over the past 3 years, the IFC has been in communication with stakeholders in the Moroccan textile industry and has launched numerous initiatives to encourage circular production. The latest initiative is a partnership with Reciclados Tangier, a Moroccan company born out of collaboration between Spanish companies, aiming to set up an ecosystem for development recycling infrastructure within textile sector in Morocco.

2. Methodology

2.1 SCOPE OF WORK

The aim of this study was to map current waste management systems, including quantities, key actors, and barriers; identify existing systems and potential business models for waste collection; and identify the necessary infrastructure to enable the collection and recycling of cotton using innovative technologies and traceability measures. The project focused on four main areas (Figure 1).

Figure 1: Main Project Areas

1. Waste Mapping

- Identify the sources and the composition of pre-consumer waste (factories, mills etc.)
- Identify the intermediary collectors and aggregators
- Establish a list of recycling and reclamation players

2. Waste Collection System

- An overview of current waste collection initiatives
- Existing framework for aggregation of waste
- Standards and operating framework for potential waste suppliers

3. Business Models

- Analysis of the economics of the textile waste sourcing at various value chain points
- Assessment of pricing models prevalent in the market

4. Traceability

- Analyse current mechanisms in place in Morocco
- Provide an overview of traceability mechanisms commonly in use globally
- Evaluate the technical and financial feasibility of implementing tracer mechanisms

2.2 PROJECT PHASES

To be able to perform the mapping and analysis, the work was conducted in three major phases: data collection and benchmarking, data analysis, and business model development.

2.2.1 Data Collection and Benchmarking

Data collection consisted of field surveys, key stakeholder meetings, and a desk review. Textile companies, waste collectors and waste recyclers were surveyed to compile data on production, volume and types of waste generated, and qualitative data on perceived challenges in the recycling system. Given the difficulty of meeting directly with these companies, phone interviews were conducted to increase the amount of data collected and reach a sample size from which extrapolation was possible. Representatives from key stakeholders were interviewed throughout the project, including the Regional Investment Center of Tangier, the textile department of the Ministry of Industry and Trade, AMITH, the School of Textile Industries and Clothing, and the Moroccan Agency for the Development of Investments and Exports. Because there were some differences in the data received, a round table discussion was organized with representatives from key stakeholders and actors from the different parts of the value chain. The results of the discussion were used to validate or update the data. The desk research focused on international best practices in key textile-producing countries, evaluation of traceability measures, technologies available for textile sorting, national benchmarks for successful waste collection systems for different types of waste, and a review of documents that IFC provided at the start of the project and of general studies.

2.2.2 Data Analysis

The main output of the study was quantification of cotton waste generated in the area around Tangier. In the first part of the analysis, two approaches were used: a top-down approach based on country-level data and analyzed based on a series of hypotheses that were corroborated through round table discussions and the Ministry of Industry and Trade and a bottom-up approach using data collected through the field surveys and phone interviews with extrapolation based on data that AMITH received.

In the second part of the analysis, the existing waste collection system was compared with international and national benchmarks to identify aspects that are working well and those that can be improved. All technological and traceability measures necessary to improve these systems were identified.

2.2.3 Business Model Development

Based on the first two parts of the analysis, business models were proposed. Options were defined, necessary investments were identified and sized, , capital and operational expenses for each option were estimated, and barriers to and requirements for successful implementation were assessed.

3. Data Collection

3.1 DATA COLLECTION FOR BOTTOM-UP APPROACH

To analyze waste flows, textile companies in the area around Tangiers were surveyed in May and June 2022. Of 122 companies contacted, 10 were visited for face-to-face interviews, and 25 were interviewed by phone. Four collectors or aggregators were also visited and interviewed (Figure 2). Separate questionnaires were used for textile companies and collectors (Annex 1).

The textile company questionnaire had four sections: general information, including production of textiles; estimate of textile waste generated; destination of waste generated; and management (e.g., sorting according to type and color, bagging, baling) and traceability of waste.

The collector and aggregator questionnaire had three sections: general information, including status (formal/informal), area covered, and type of activity (collection, sorting, processing); estimate of textile waste collected; and management of waste, including treatment of collected waste, traceability system, and transport.

The findings of the survey were discussed and confirmed during a round table discussion on July 27 in Tangier with the main stakeholders in the textile sector (Figure 3). A complete list of participants is provided in Annex 2.

Figure 3: Round Table Discussion

Figure 2: Location of Companies Visited

The data collection methodology and preliminary findings were presented, followed by a discussion with stakeholders. The first important discussion point was about the difficulty of assessing waste quantities; all stakeholders agreed that this is because of the variability in production, with periods without any orders and other periods with many. Although it is difficult to make accurate estimates, the methodology presented (bottom up approach) was the best approach, and the waste quantities were in line with their estimates. The Ministry of Industry and Trade later confirmed the estimates. The second point discussed was that cotton waste is of high value and that there are many initiatives for collecting and recycling pre-consumer textile waste. The stakeholders agreed that the next focus should be on mixed textiles and automotive textiles because there is much more of such textiles, and the recycling options are limited. Finally, many stakeholders involved in collection and recycling claimed that they did not have difficulty accessing cotton or textile waste in general and were interested in discussing investment opportunities directly with financial institutions.

The survey of the 35 textile companies in the area around Tangier provided estimates of the quantity of total and 100 percent cotton waste that they generate (Table 1).

Table 1: Cotton Waste

Company	Annual production capacity (pieces)	Total cutting waste (tons/year)	Cotton waste (%)
1	7,800,000	413	ND
2	6,500,000	344	ND
3	4,800,000	254	ND
4	3,600,000	191	ND
5	3,600,000	191	ND
6	2,880,000	152	ND
7	2,860,000	151	30
8	2,700,000	143	ND
9	2,340,000	124	ND
10	2,160,000	114	ND
11	2,000,000	106	ND
12	2,000,000	170	ND
13	1,800,000	95	ND
14	1,680,000	89	5%
15	1,620,000	86	ND
16	1,440,000	76	ND
17	1,440,000	76	ND
18	1,260,000	67	ND
19	1,260,000	67	ND
20	1,200,000	64	ND
21	1,200,000	64	ND
22	1,080,000	57	ND
23	1,080,000	57	ND
24	960,000	51	20
25	900,000	62	13
26	840,000	44	ND
27	800,000	42	ND
28	720,000	38	30
29	720,000	109	30
30	480,000	25	ND
31	360,000	31	ND
32	216,000	11	ND
33	180,000	10	35
34	30,000	9	15
35	20,000	3	ND
Total	**64,526,000**	**3,587**	**22**

Note: ND: Not Determined.

Cotton waste accounts for approximately 20 percent of total waste that textile companies in the area around Tangier generate.

3.2 DATA COLLECTION FOR TOP-DOWN APPROACH

In addition to field data, data extracted from the Foreign Trade Database of the Foreign Exchange Office regarding exports and imports of raw materials (Table 2) were used to estimate the quantity of cotton raw material entering and used in Morocco (net imports) from 2011 to 2021 and to estimate the quantity of waste generated in Tangier.

To confirm these data, export data were requested and obtained from the Ministry of Industry and Trade. The data were also compared with results of other studies, in particular the UNIDO study, to determine their reliability.

Figure 4 shows average imports of cotton raw material according to composition during 2011 to 2021; cotton fabrics and fibers account for 65.6 percent of total imports that include cotton.

Figure 4: Average Cotton Net Imports, 2011-2021

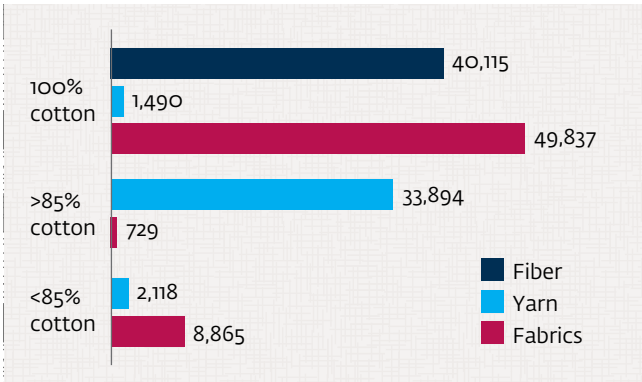


Table 2: Import and Export Data

	Imports (kg/year)				
Data source	2017	2018	2019	2020	2021
Ministry of Industry and Trade (Portnet)	142,014,420	136,763,112	133,815,953	108,099,594	144,723,468
Foreign Exchange Office	142,016,437	136,765,130	133,817,972	108,101,614	144,725,489
	Exports (kg/year)				
Data source	2017	2018	2019	2020	2021
Ministry of Industry and Trade (Portnet)	10,801,258	9,183,283	8,661,221	7,583,312	9,346,838
Foreign Exchange Office	10,803,275	9,183,283	8,661,221	7,583,312	9,346,838

There was a spike in imports of raw material in 2015 at the start of Morocco's Industrial Acceleration Plan and the signing of large orders through trade shows, but imports fell in 2020 because of the COVID-19 pandemic (Figure 5). Imports of cotton fiber fell after 2015, indicating the reduction in yarn spinning. Cotton fabric and yarn imports are gradually increasing as the pandemic has eased.

Figure 6 shows average imports (2011-2021) of cotton fabric according to composition and color. Most is colored, whereas recyclers are primarily interested in white or ecru.

Figure 5: Net Cotton Imports

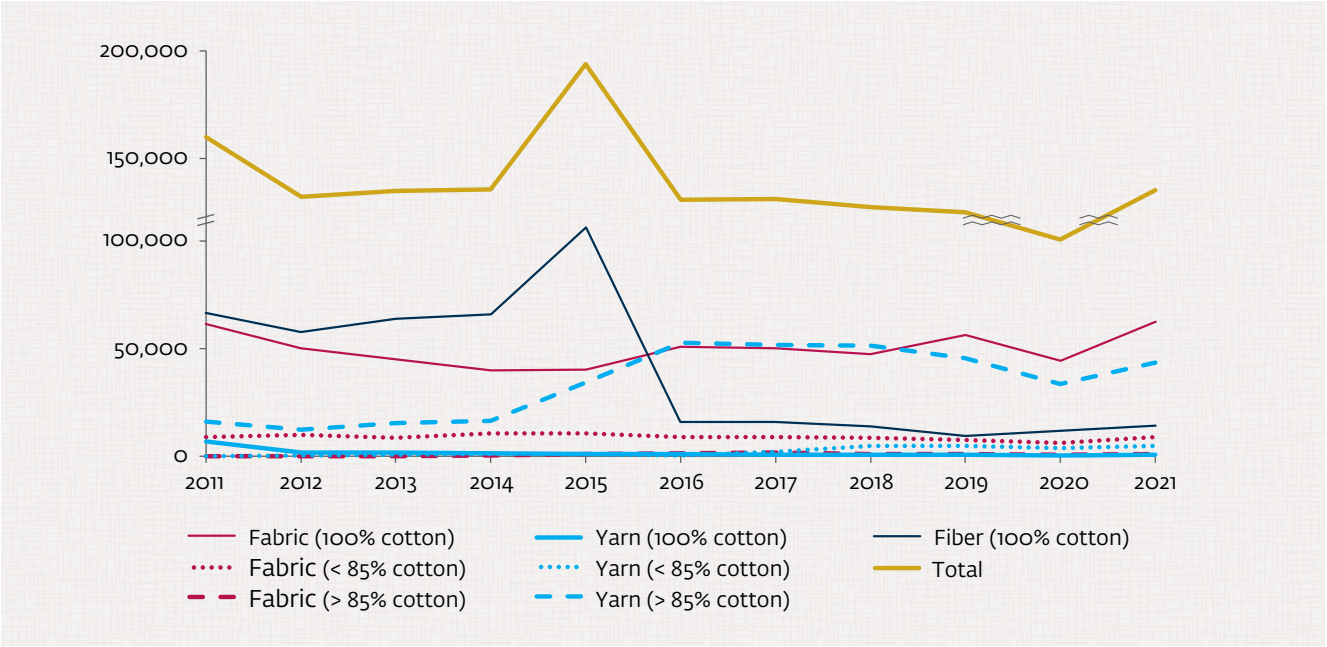
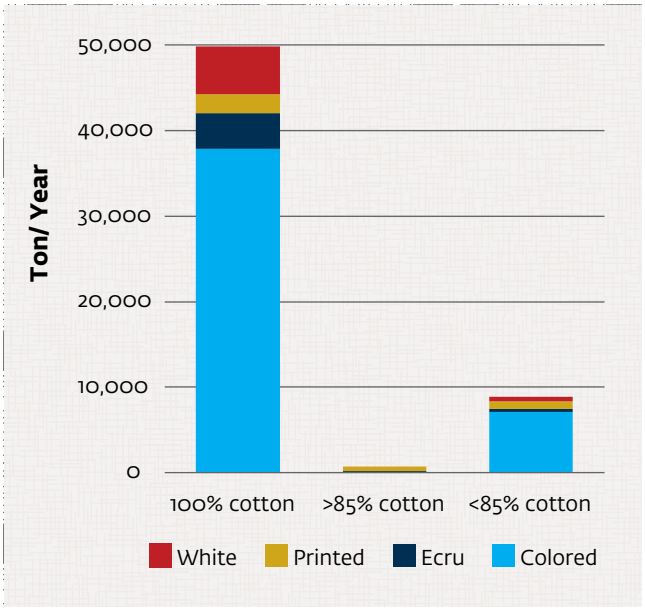


Figure 6: Net Imports of Cotton Fabric According to Color, 2011-2021



4. Textile Waste Mapping

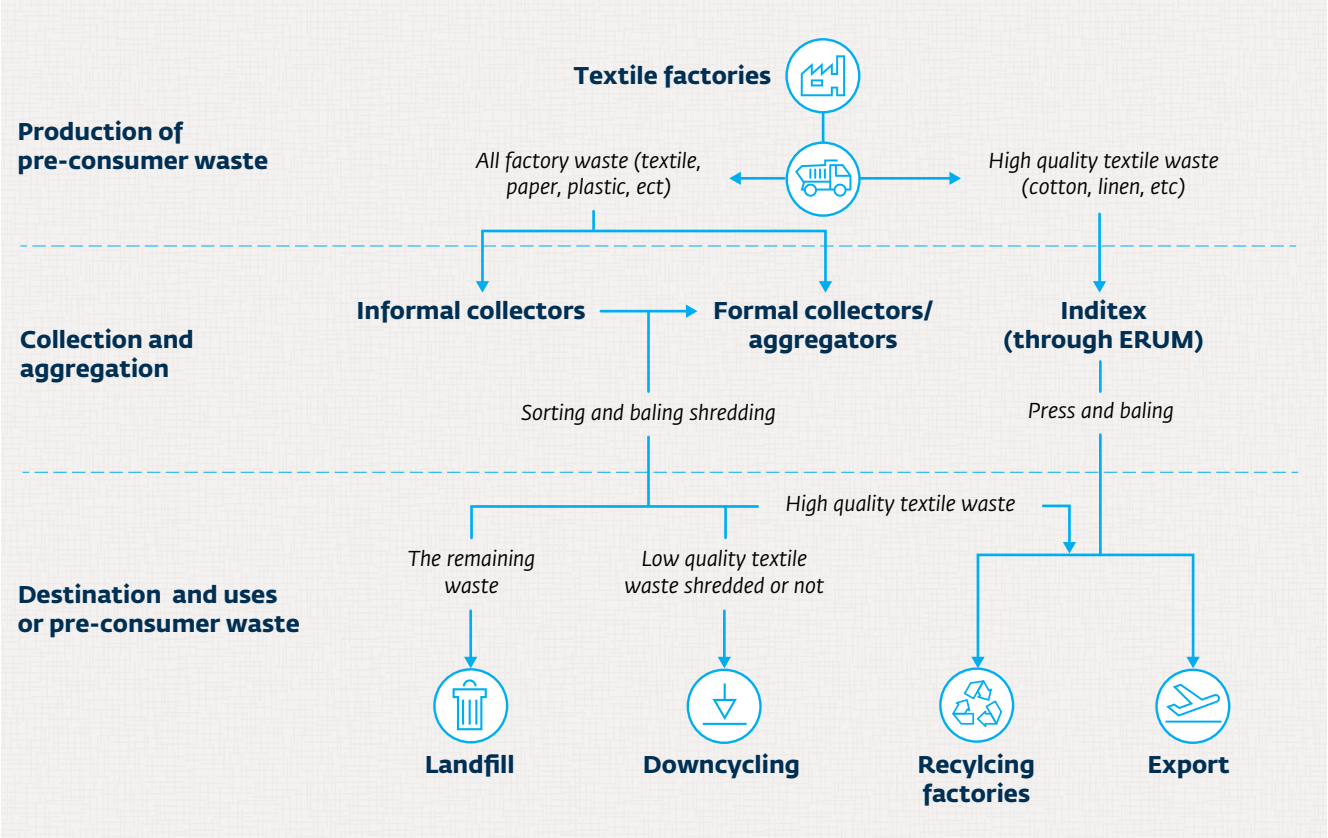
4.1 GENERAL FLOW OF WASTE IN THE TANGIER AREA

Textile waste that textile companies in Tangier generate can follow one of two paths. If the customer requests the waste, the companies separate and bale it and provide a traceability sheet. Only high-quality textile waste such as 100 percent cotton and linen follow this path. After the collection company presses and bales the waste, recyclers in Morocco use it, or it is exported. If the customer does not request the waste, the companies rely on a collector to collect it along with the rest of their waste (e.g., paper, plastic) and do not sort it or provide a traceability sheet; collectors collect the waste as it is generated and sort it in their warehouses. The final destination of this can be a recycler or export for high-quality waste or downcycling or landfill for low-quality waste. Figure 7 shows the cotton textile waste value chain.

4.2 DATA ANALYSIS AND ESTIMATE OF WASTE (BOTTOM-UP APPROACH)

The estimation for approximately 300 companies in Tangier was based on two sets of extrapolations. The first extrapolation was to estimate the waste for 122 companies from the data collected from a sample of 35 companies by calculating their share of the total revenue of the 122 member companies of AMITH (29 percent), of the number of companies (27 percent), and of the number of employees (32 percent). Based on this evaluation, our sample accounts for 27 percent to 32 percent of AMITH members. The slight differences between the three methods to calculate sample size shows that the companies within our sample are a good representation of the larger sample. To estimate the total amount of waste in the area which is comprised of 300 companies, a simple extrapolation was done from the previously estimated waste

Figure 7: Cotton Textile Waste Value Chain



generated from 122 companies. The Ministry of Industry and Trade, AMITH, and Inditex (according to its website) confirmed the total number of companies. According to the extrapolation, 31,500 tons of total textile waste and 6,200 to 7,300 of 100 percent cotton waste are generated per year in Tangier.

The following assumptions were used to complete the estimates: the 15 percent of material used for production is discarded (confirmed by round table discussion and the Ministry of Industry and Trade), and the average weight of a piece is 300 grams (which was used for companies that provided information on production in number of pieces but did not give an estimate of waste).

4.3 DATA ANALYSIS AND ESTIMATE OF WASTE (TOP-DOWN APPROACH)

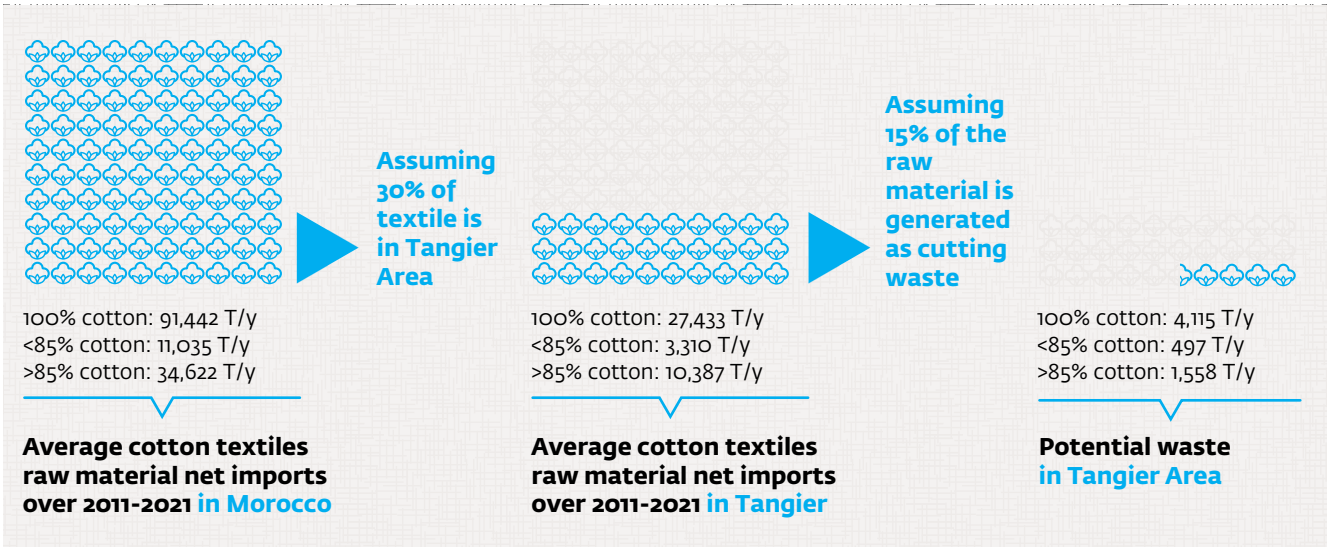
Import and export data were used to estimate textile waste generated in Tangier using the following assumptions[4]:

- Average waste generated is 15 percent of the total raw material used in production.
- Tangier accounts for 30 percent of Morocco's textile production.
- Textiles used in production are evenly distributed across the country and the area.
- Yarn and fiber quantities are accounted for within the 15 percent of waste generation as they will be transformed into fabrics and used in local production (waste generated during spinning and weaving are negligible compared to cutting waste).

All the assumptions have been discussed with various stakeholders, including the Ministry of Industry and Trade, AMITH, textile companies, and collectors and confirmed. During the round table discussion, the distinction was made between temporary entry conditions (which allows companies to import textiles to transform into finished products and then export the finished products without paying tariffs) and regular imports (for which companies pay tariffs on all imports). Customs regulation in Morocco allows for 22 percent of imported fabrics to remain in Morocco and the rest must be exported after transformation. Of the imported quantities remaining in Morocco, some are used to produce clothing or other textile products depending and the rest is waste. Based on the discussion, it is estimated 15 percent of imported textiles enter the waste stream and 7 percent are used to produce various textile products for the local market.

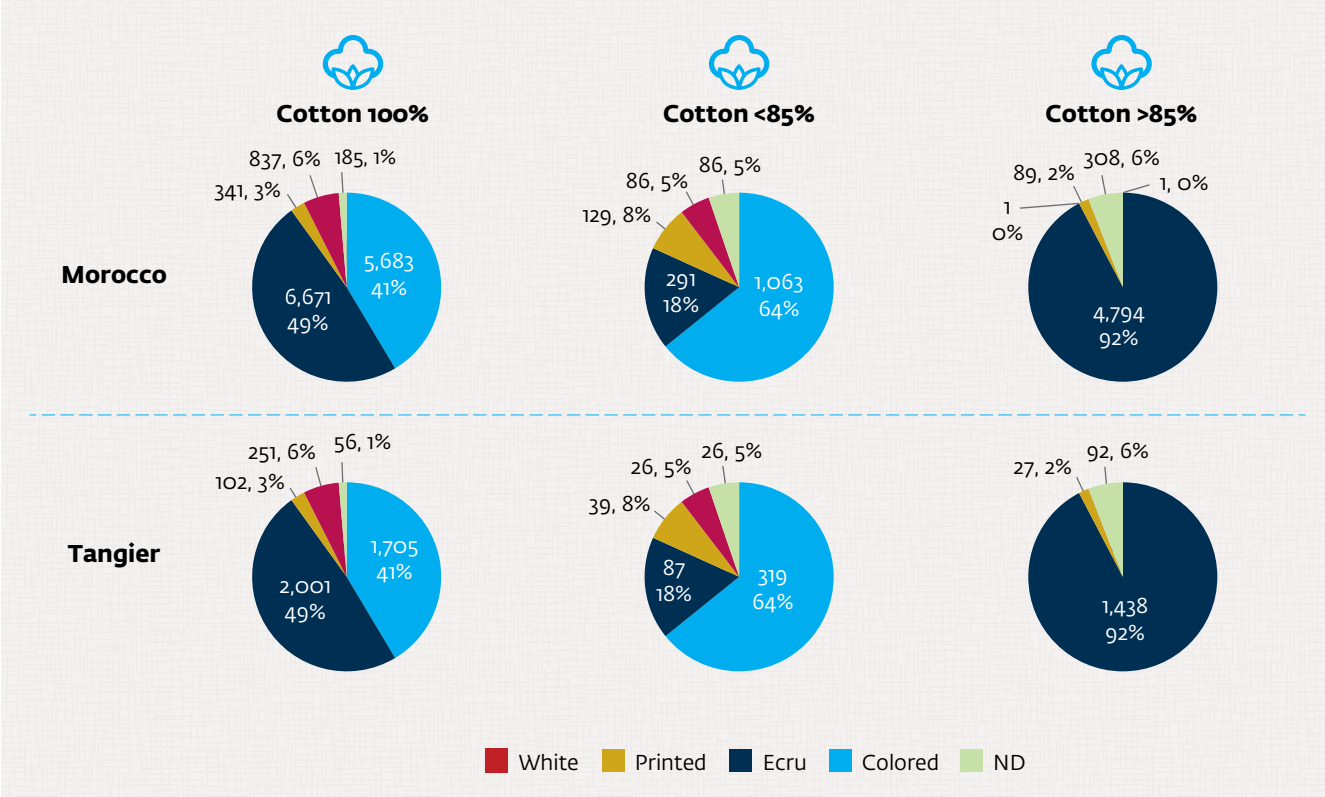
Figures 8 and 9 show the estimates of textile waste in Tangier:

Figure 8: Textile Waste in Tangier



4 Data sources discussed in section 3.

Figure 9: Textile Waste According to Color



Note: ND,: Not determined

4.4 MAPPING OF EXISTING COLLECTION SYSTEMS

Three main collection systems have been identified:

1. **Multi-waste recyclers take all**
   For this system, collectors collect waste in bulk or in bags from textile factories; transport it to their warehouses; and then sort, store, shred, and sell it (Figure 10).

   Collectors sell cotton waste for 1.5 to 2 dirhams/kg, mixed waste for 0.2 to 1 dirhams/kg, and shredded waste for 2 dirhams/kg.

Figure 10: Textile Waste Before and After Sorting by Collectors

2. **Waste returned to supplier**
   If the customer supplies the raw material and requests to have the textile waste returned, the companies separate and bale the waste and provide a traceability sheet (Figure 11).

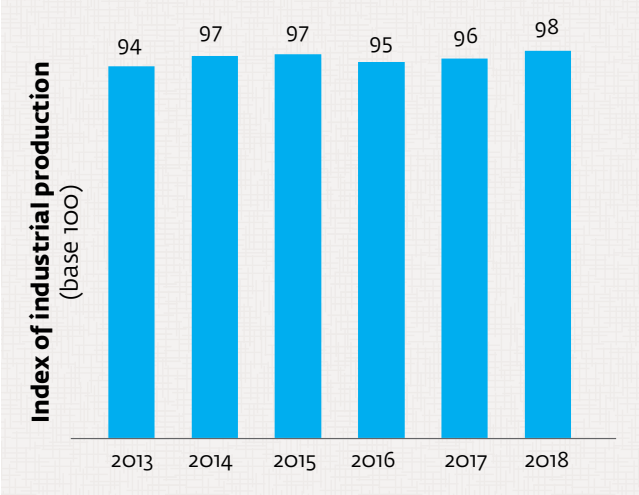
Figure 11: Separation and Identification of Textile Waste Requested by Customer

3. **Industrial zone manages waste**
   In the Tangier Free Zone (TFZ), the zone manages waste, but textile waste is not separated and undergoes the same treatment as other waste.

4.5 WASTE PROJECTIONS

An important part of identifying investment opportunities in waste valorization is securing the supply of the targeted waste. Although generated waste quantities are currently available for recycling, it is important to consider future trends. Based on the import history, the volumes show that the trend is slightly upward. The production index (Figure 12) shows an almost constant market, with slight fluctuations from year to year.

Figure 12: Textile Production Index for Morocco, 2013-2018



Note: https://fr.statista.com/statistiques/916785/industrie-textile-indice-production-maroc/

Trends and forecasts are difficult to determine given the lack of historical data and detailed information on the sector. Based on expert opinion, macroeconomic data on the sector, and general market trends, there are three forecast scenarios:

1. Based on textile market growth over the past 10 years in Morocco and net import data obtained from the Ministry of Industry and Trade, cotton waste generation will remain level over the short and long term.
2. Increasing adoption of waste minimization practices and eco-design will decrease waste from the current 15 percent estimate to less than 5 percent over the long term.
3. The textile sector remains a strategic sector in Morocco, with prospects for job creation and revenue generation. If the growth strategy is successful, production will increase, and waste will grow accordingly over the long term.

5. Benchmarking

This section explores the benchmark that the study team developed for pre-consumer textile waste in five major manufacturing countries to analyze cellulosic fiber waste sourcing processes. The objective is to highlight relevant experiences of textile waste sourcing processes in Bangladesh, China, Egypt, India, and Turkey.

The key factors for selection were leadership in the textile market and experience in textile waste recycling, including cotton waste.

- **Bangladesh** generates a large volume of textile waste and generates the most recyclable textile waste.
- **China** is the leading global producer and exporter of raw textiles and apparel and one of the largest cotton producers.
- **Egypt** has high growth potential in post-industrial cotton textiles.
- **India** has the third largest textile manufacturing industry and was a top exporter of cotton waste in 2020.
- **Turkey** is one of the four largest global textile exporters and one of the top 10 cotton producers.

This section of the report presents key data from these five countries' textile industries, including exports, imports, and textile waste volume, and provides an overview of textile waste collection systems, routes and logistical frameworks, and aggregation of waste and recycling systems.

5.1 WASTE COLLECTION SYSTEMS

This section describes the textile and apparel industry in each country and how they manage their textile waste and then selects best practices to be implemented in Morocco.

Although textile and apparel industry practices vary from country to country, they each have explored ways to reduce and recycle textile waste.

5.1.1 India: Largest Cotton Producer

5.1.1.1 Textile and Apparel Industry

The textile and apparel industry in India accounted for approximately 2 percent of the country's gross domestic product (GDP) in 2019.[5] India is the sixth largest global exporter of textiles and apparel and accounts for 4 percent of global trade in textiles and apparel. The textile sector is the second largest employer in India after agriculture, employing more than 45 million people.[6]

5.1.1.2 Cotton Fiber

India is one of the largest consumers and producers of cotton, which is one of the most important commercial crops grown in the country, accounting for approximately 25 percent of global cotton production.[7] It is estimated that 5,700 tons of cotton was produced in 2019/2-. Cotton accounted for 56 percent of total fiber exports in 2019/20.

5.1.1.3 Textile Waste

Textile waste is the third largest source of municipal solid waste in India.[8] More than 1 million tons of textiles are thrown away every year,[9] making it a major source of pollution.

India's production and consumption of textiles and apparel generates large streams of pre- and post-consumer waste.

- **Pre-consumer waste,** known as "clean waste," is generated in the various stages of manufacture from fiber to fashion (spinning, weaving, knitting, sewing). It is estimated that up to 25 percent of fabric is lost during the manufacture of apparel.[10]
- **Post-consumer waste** is imported mainly from North America and Europe with a mix of textiles including wool, cotton, acrylic and denim.

5 https://aepcindia.com/system/files/Annual%20T%20and%20A%20Industry%20Report-2021.pdf
6 https://www.investindia.gov.in/sector/textiles-apparel
7 http://texmin.nic.in/sites/default/files/Cotton%20Sector.pdf
8 https://circularapparel.co/blog/2020/07/13/where-does-textile-waste-go/#_ftn1
9 https://www.tsijournals.com/articles/circular-economy-for-textiles-as-engrained-in-the-traditional-indian-life.pdf
10 https://circularapparel.co/blog/2020/07/13/where-does-textile-waste-go/

5.1.2 Egypt: Largest Producer of Extra-Long Staple Cotton in Africa

5.1.2.1 Textile and Apparel Industry

The textile and apparel industry in Egypt accounts for almost 3 percent of GDP and employs 1.5 million workers, 50 percent of whom are women. The sector accounts for 27 percent of Egypt's industrial output and 12 percent of overall exports.[11]

Egypt's main textile export destinations are the European Union (35 percent), Turkey (30 percent), the Middle East and North Africa (23 percent), and the rest of Africa (10 percent).

The top exported fabrics are denim and cotton fabrics (55 percent), woven and synthetic fabrics (21 percent), and knitted fabrics (13 percent).

5.1.2.2 Cotton

cotton is among the purest and absorbs liquids well, meaning that it is brighter and more resistant-colored fabrics.

5.1.2.3 Textile Waste

Egypt's textile industry generates more than 212,000 tons of pre-consumer textile waste per year,[12] 80,000 tons of which is 100 percent cotton, and 28,000 tons is classified as cotton-rich waste (at least 50% cotton).

The spinning stage is responsible for 11 percent of pre-consumer waste. The waste generated during this phase can be sorted and the cotton portion can be identified relatively easily for future recycling. Bangladesh: Opportunity to Implement a Circular System

5.1.2.4 Textile and Apparel Industry

The textile and apparel sector in Bangladesh accounted for almost 11.4 percent of GDP and employed 4 million people in 2018/19. Apparel exports from Bangladesh were $34.1 billion in 2018/19.

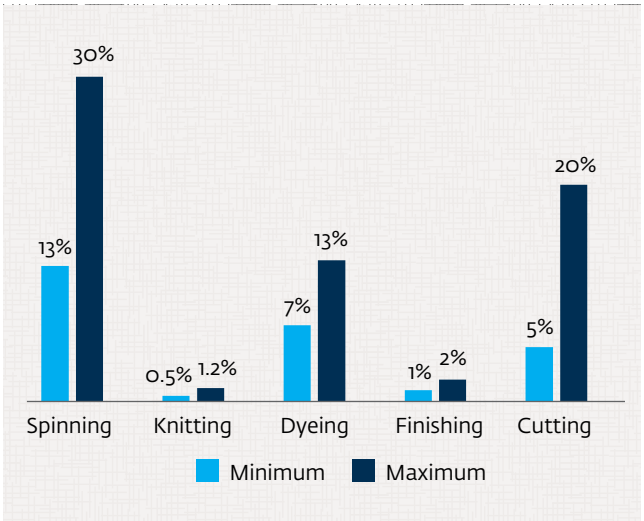
5.1.2.5 Cotton Fiber

In 2018/19, the Cotton Development Board estimated that 143,000 bales of cotton (31,200 tons) were produced on 44,000 hectares. In 2019, Bangladesh imported 1.63 million tons of staple cotton fiber with an estimated value of US$3.5 billion.

5.1.2.6 Textile Waste

Bangladesh's textile and apparel industry generated approximately 577,000 tons of waste, 250,000 tons of which was 100 percent cotton. Most of the waste could be recycled. Figure 13 illustrates the waste from knitting (0.5-1.2 percent), cutting (5-20 percent), and spinning (15 percent).[13]

Figure 13: Contribution of Textile Processing to Total Textile Waste



5.1.3 Turkey: Fourth Largest Textile Exporter

5.1.3.1 Textile and Apparel Industry

Turkey is the seventh largest global textile exporter (US$9.8 billion). The textile and apparel sector employs approximately 1 million workers.

5.1.3.2 Cotton Fiber

In 2020, Turkey was the seventh largest global cotton producer, producing an estimated 3.7 million bales on 590,000 hectares in 2019/20.

5.1.3.3 Textile Waste

Turkey generates 1.3 million tons of textile waste annually. In 2020, it exported US$59.9 million worth of cotton waste, making it the second largest global exporter of cotton waste.

11 https://kohantextilejournal.com/apparel-and-textiles-sectors-in-egypt/
12 https://switchmed.eu/wp-content/uploads/2022/01/MED-TEST-III-EGYPT_DA_9_TextileWasteMapping.pdf
13 https://www.textiletoday.com.bd/waste-to-fashion/

5.1.4 China: Largest Apparel Producer and Exporter

5.1.4.1 Textile and Apparel Industry

China has nearly 44,000 companies producing textiles and apparel, employing 6.4 million people. In 2018, China's fiber processing volume was 54.6 million tons, accounting for more than half of global fiber processing volume.

5.1.4.2 Cotton Fiber

China is the largest global producer of cotton, with 3.2 million hectares planted in 2020. In 2019, total cotton output was 5.93 million tons.[14]

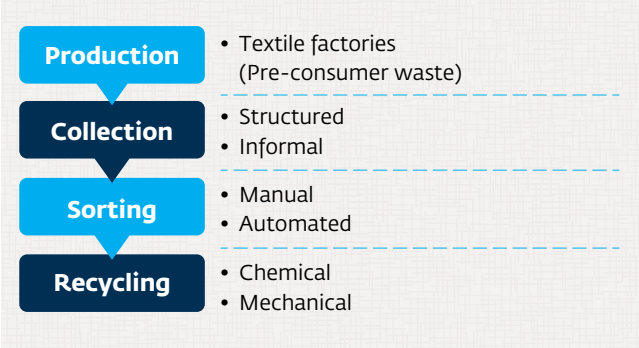
5.1.4.3 Textile Waste

China disposes of 20 million tons of textile waste annually. Production accounts for 12 percent of fiber loss.[15]

5.2 TEXTILE WASTE VALUE CHAIN

Building circularity in the textile value chain is challenging. Each country aims to create a formal system to use waste as a resource for making new products. There are four processes in the textile waste value chain (Figure 14).

Figure 14: Textile Waste Value Chain



There are two types of collection systems:

1. **Structured systems** are based on contracts between collectors and aggregators.
2. **Informal systems,** which are dominant in all five benchmark countries, involve informal collectors who collect waste from textile industries (e.g., chindi wallas or kabadiwalas in India, zabbaleen in Egypt).

There are two types of sorting systems.

1. **Manual sorting** is more common.
2. **Automated sorting** is based on new technologies.

The main criteria for sorting textile waste are size, color, and fiber type.

There are two types of fiber recycling systems.

1. **Chemical recycling** uses a series of processes to depolymerize fibers from fabric into monomer (solvent) form to make a new fiber compound or extract one compound from a mix.
2. **Mechanical recycling** includes shredding and carding to extract fibers from fabric. It is more common because it is one of the easiest and least-expensive recycling methods.

The following sections highlight how the five selected countries collect, sort, and recycle pre-consumer textile waste.

5.2.1 India

Panipat is the textile recycling center in India, where pre- and post-consumer textiles are recycled. This subsection focuses on pre-consumer waste supply chains in Panipat.[16]

5.2.1.1 Collection and Transport System

Chindi wallas collect waste packed into balls or in bulk, load it into a rickshaw or truck, and transport it to a collection center. Transportation charges are approximately US$0.052/kg per kilometer. Most of this waste is sold to waste workers for US$0.078 to US$0.13 per kilogram. Pre-consumer cotton waste is sold for US$0.20 to US$0.80 per kilogram.

5.2.1.2 Sorting and Aggregation of Waste

Some large collectors rent spaces where they sort waste according to the demands of buyers. Some small collectors depend on homeworkers and family members, sorting waste on the side of the road in front of their houses.

Waste is sorted based on size, color, and fabric type, such as cotton, wool, or acrylic.

14 https://lindstromgroup.com/article/value-creation-with-textile-waste-in-china/
15 https://global-recycling.info/archives/3228
16 https://arisa.nl/wp-content/uploads/TextileRecyclingUnravelled.pdf

5.2.1.3 Recycling System

India is a global hub for mechanical recycling. The textile recycling sector employs more than 1 million people, has annual revenues of approximately US$2 billion, and processes approximately 5 million tons of material. Recycling pre-consumer waste involves bleaching, washing, shredding, and converting the shredded material into recycled yarn.

5.2.2 Egypt[17]

In Egypt, collectors recover textile waste to supply to clients who have ordered it or approach them once they have available waste. They use plastic bags to collect the waste and transport it in a donkey cart. Since 2010, they have cargo motorcycles.

The Zabbaleen community is famous group of informal waste collectors where their name means garbage collector in Arabic. They live in the Mokattam village where they sort the waste a prepare it to be sold to recyclers.

Collectors sell the material to apparel factories close to or in Zawia (a zone where people bring their old possessions).

Other collectors, who are independent of the Zabbaleen community, sell their material to collectors/aggregatorsof recycled textiles or private recycling companies.

5.2.3 Bangladesh[18]

The price of pre-consumer waste varies depending on product category and season: US$0.14 to US$0.34 per kg for waste produced during the cutting phase and US$0.40 for recycled cotton fiber, which is approximately 20 percent of the price of cotton fiber.

The first step in the recycling process is manual sorting to separate the different colors. Fabric scraps are then processed in a recycling machine, which shreds the fabrics into cotton fibers, which are pressed into bales.

5.2.4 Turkey

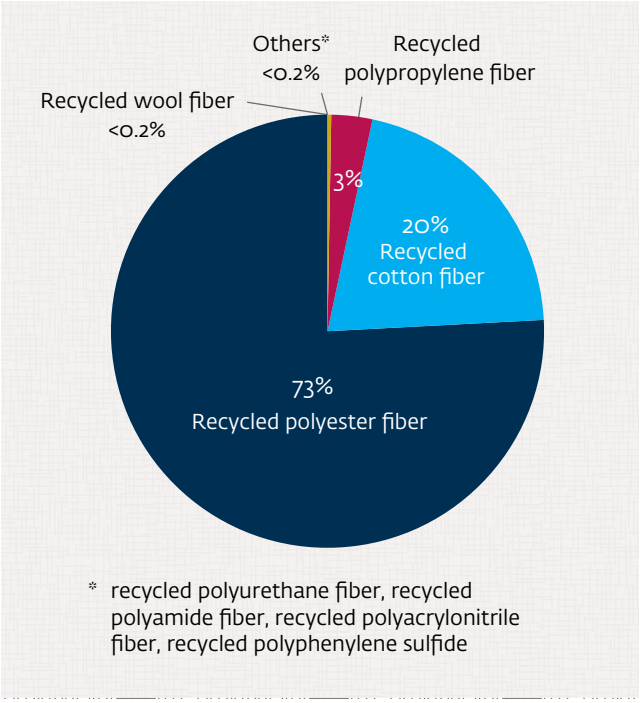
In Turkey, the informal collection system is dominant. Waste is collected and sold to bigger collection and storage companies without any tax payments or proof of exchange. Once the waste fabric arrives at the recyclers, it is processed into fiber or yarn and returned to the textile production value chain within the country or abroad.

5.2.5 China[19]

After collection, textile waste is sorted according to condition, fiber composition, and color. Some Chinese companies have introduced a high-speed near-infrared textile identification and sorting system. Other companies developped a system by combining near-infrared technology with automatic sorting equipment in collaboration with universities.

One of the largest cotton recycling companies is Cangnan in Zhejiang Province. It processes 80 percent of the textile scraps in China every year and produces about 2 million tons of recycled cotton yarn. Figure 15 shows the categories of recycled fibers in China in 2018.

Figure 15: Main Categories of Recycled Fibers in China



17 https://restopia.info/wp-content/uploads/2017/06/Dossier_Presse_Mucem_Ordures_EN.pdf
18 https://www.sciencedirect.com/science/article/pii/S2666789422000010
19 https://www.switch-asia.eu/site/assets/files/2628/make_fashion_circular-outlook_for_a_new_textiles_economy-_-20201201.pdf

5.3 FRAMEWORK TO PROMOTE RECYCLING OF TEXTILE WASTE

The benchmark countries have different government initiatives, projects, and frameworks to promote textile waste recycling. This section details the regulation systems, initiatives, and partnerships that these countries have developed.

5.3.1 Laws and Regulations

Some countries have started to implement a policies in circular economy to enable the textile processing sector to meet environmental standards through appropriate technology.

India has a clear vision for circularity in the textile sector and has established the Integrated Processing Development Scheme to help textile processors meet environmental standards that the government has established.[20] In January 2016, India launched the Amended Technology Upgradation Fund Scheme to increase productivity, reduce costs and waste, and improve quality along the value chain.

China has implemented several regulations on circularity in the textile sector:[21]

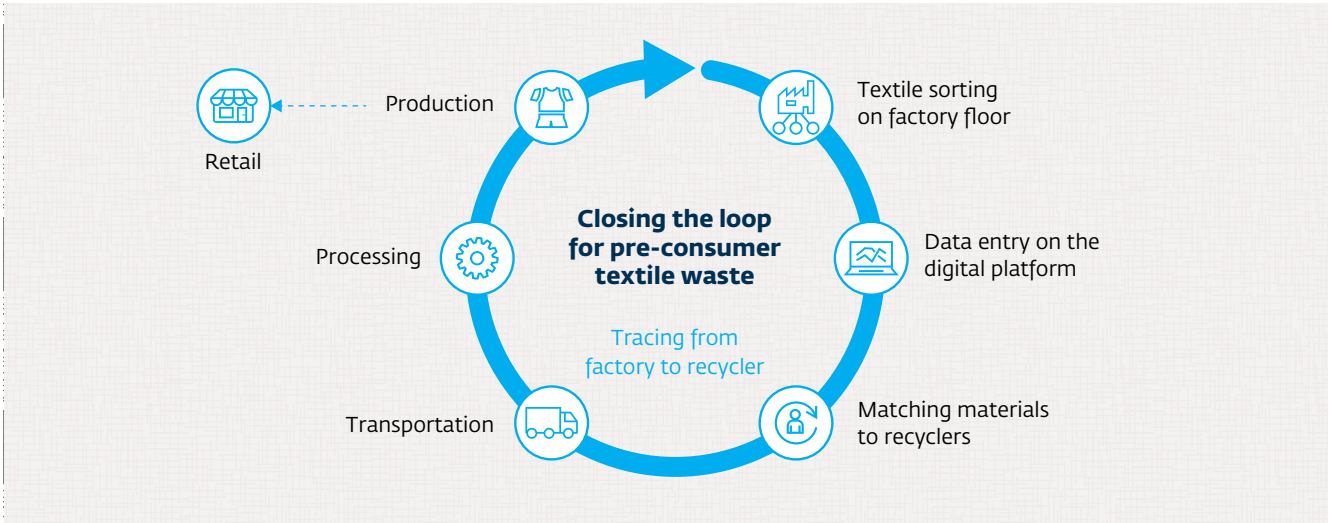
- The Development Plan for the Textile Industry (2016-2020) helped increase the proportion of recycled fiber used in production from 9.6 percent in 2010 to 11.3 percent in 2015, reaching 8 million tons of reused textile fiber in the textile industry.
- The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020) had the objective of recycling 4.5 million tons of textiles by 2020. As a result, China recycled between 1.5 and 2 million tons of cotton in 2018.
- The Circular Economy Development Strategies and Action Plan 2013 included a focus on replacing raw materials with recycled material, reducing consumption, conserving energy and recycling resources in production, standardizing textile waste recycling, and building a circularity within the textile industrial value chain.

5.3.2 Partnership and Collaboration

One of the famous partnerships in India is Sorting for Circularity India (Figure 16), which Fashion for Good launched and Laudes Foundation supported in November 2021. The project's goal is to build an accessible infrastructure for manufacturers, sorters, collectors, waste handlers, and recyclers. It ensures traceability and provides incentives for the use and scale-up of new technologies in India.

Aditya Birla Apparel and Retail Limited and the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH are implementing the DeveloPPP program on behalf of the German Federal Ministry for Economic Cooperation and Development to increase textile-to-textile recycling, develop alternatives to plastic packaging, and increase traceability.

Figure 16: Pre-Consumer Textile Waste Loop



20 https://www.indiafilings.com/learn/ipds-scheme/
21 https://www.switch-asia.eu/site/assets/files/2628/make_fashion_circular-outlook_for_a_new_textiles_economy-_-20201201.pdf

Bangladesh launched the Circular Fashion Partnership in 2020, led by the Global Fashion Agenda and partners with Reverse Resources[22], with the goal of creating circular commercial collaborations between 43 textile and apparel manufacturers, 17 recyclers, one buying agent, and 20 major global fashion companies, including Inditex. It enables the sale of textile waste via a recycling exchange platform (online market).

Turkey designed the Circular Economy Platform, which the Business Council for Sustainable Development Turkey and the European Bank for Reconstruction and Development established in 2016 with the goal of providing practical solutions, incentives, news, and opportunities in circular economy. The platform includes a knowledge hub and an e-commerce platform (Turkey Materials Marketplace) and offers training, financial opportunities, and consultancy services for companies that are looking to accelerate their transition to a circular system. It creates circular commercial collaborations between fashion industry, manufacturers, and recyclers.

Another project, which the Netherlands and the European Bank for Reconstruction and Development launched together, is the Circular Voucher Scheme 2.0 (which is designed to help Turkish companies identify viable investments that can enhance circularity and provide technical assistance to member companies through the online platform Turkey Materials Markets.[23]

5.3.3 Projects and Initiatives

UNIDO implemented the Egyptian Cotton Project in cooperation with the Ministry of Trade and Industry and local and international private textile sector stakeholders to encourage textile circularity in Egypt.

Koton Exim, in India, has developed 100 percent–recycled cotton yarns from cotton waste.

A leading manufacturer of cotton yarn and exporter of cotton yarn, cotton waste, and raw cotton, Säntis Textiles, in Turkey, recycled 100,000 tons of cotton waste in 2021.

SIMCO Spinning & Textiles is the exclusive producer in Bangladesh of CYCLO recycled fiber, one of the most environmentally friendly textiles.

The Realist Project, launched by KnitwearLab, aimed to used textile waste generated in Turkey to developed a small collection made with at least 40 percent post-industrial recycled textile waste. Additionnally, Turkey's first lady, Emine Erdoğan, launched the Zero Waste NØW project in 2017, with an investment of US$183.9 million financed by the European Bank for Reconstruction and Development and US$13.06 million provided by the Financial Investment Council. The project enabled annual reductions of 513,700 tons of carbon dioxide per year and 814,665 tons of raw materials.

5.4 SPANISH INITIATIVES: NEAR-INFRARED SPECTROSCOPY

The Modacc Cluster[24], in cooperation with the textile technology center FITEX, the Polytechnic University of Catalonia, and the University of Lleida, has launched the Automatic Textile Sorting project, which enables materials to be classified based on type of textile and fiber using near-infrared spectroscopy and can determine with great precision the presence of up to 13 types of fibers. It is estimated that 87,000 euros has been invested in the project.

5.5 EU STRATEGY FOR SUSTAINABLE AND CIRCULAR TEXTILES

Because the textile value chain is complex and the fourth largest sector in terms waste production in Europe, the European Union has created a strategy dedicated to waste reduction in the textile sector.

The European Union's introduction of extended producer responsibility will require that producers manage the waste that their products create, which will encourage product design that promotes circularity. This is expected to be part of the Waste Framework Directive in 2023. The strategy includes new requirements for eco-design of sustainable products will set eco-design and information requirements, including a digital product passport. The European Commission proposed that large companies be required to disclose publicly the number of products they discard or destroy and those they reuse or recycling.

22 https://reverseresources.net/
23 https://donguselekonomiplatformu.com/en/
24 https://www.modacc.cat/

Exports of textile waste to non–Organization for Economic Cooperation and Development countries will be allowed only if such countries notify the European Commission that they are willing to import specific types of waste and demonstrate their ability to manage it sustainably.

5.6 NATIONAL BENCHMARK

In Morocco, many other waste streams have been moving toward circularity and recycling. Two main value chains are plastics and paper and cardboard. Plastics are similar to textiles in that there are many different types, with the most sought-after being polyethylene terephthalate. This can be correlated with textiles, whose recycling loop is focused on cotton and not other textiles.

5.6.1 Plastic Waste Value Chain

5.6.1.1 Plastic Industry in Morocco

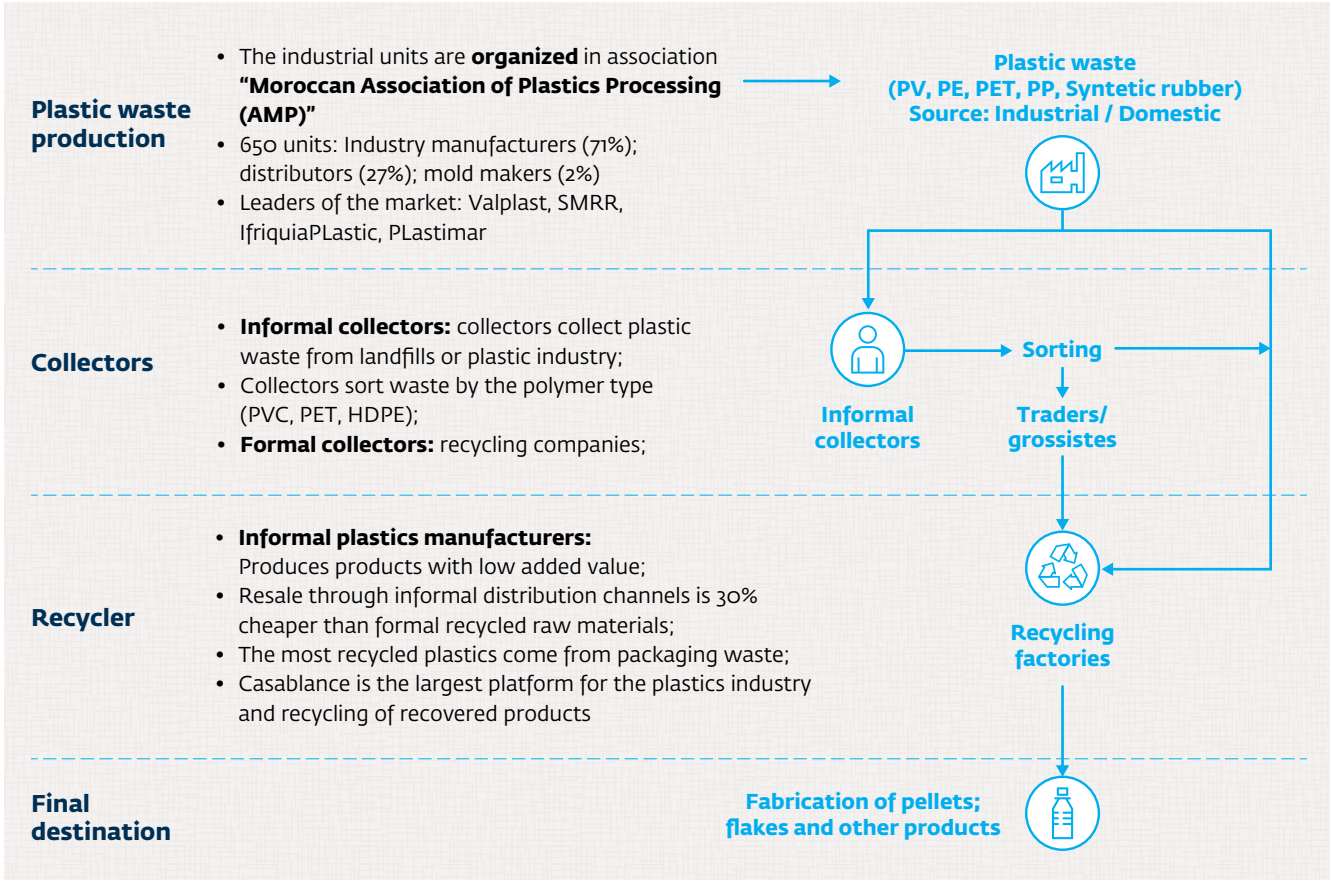
The plastics industry is an important sector in Morocco, with annual revenues of approximately 13.5 billion dirhams, projected to reach 28 billion dirhams in 2023. It provides more than 352,000 jobs. The sector has approximately 650 factories (71 percent processors, 27 percent distributors, 2 percent molders) and processes 550,000 tons of raw materials annually. Casablanca produces and recycles the most plastic in the country. The largest companies are Valplast, the Société Marocaine de Récupération et de Recyclage, IfriquiaPlastic, and Plastimar. As it is the case for most industries in Morocco, the plastic industry actors have created an association to represent them : Moroccan Association of Plastic Processing.

5.6.1.2 Plastic Waste Management

Collectors gather plastic waste, sort it according to polymer (polyvinyl chloride, polyethylene terephthalate, high-density polyethylene), and deliver it to recyclers, who crush and clean it and deliver it to recyclers.

Figure 17 illustrates the structure of the plastic waste value chain.

Figure 17: Plastic Waste Value Chain



5.6.2 Paper Waste Value Chain

5.6.2.1 Paper Industry in Morocco

The Moroccan paper industry was established in the 1960s and has been an important sector in the country's development. Domestic production satisfies 50 percent of consumption for printing and packaging paper, the rest being mainly imported from Europe. The industrial plants transforming paper and cardboard are organized in the Federation of Chemistry and Para-chemistry located in Casablanca. There are 62 manufacturers and processors in the Moroccan market, although four dominate: Compagnie Marocaine des Cartons et des Papiers, Med Paper, Lex Papier, and GPC.

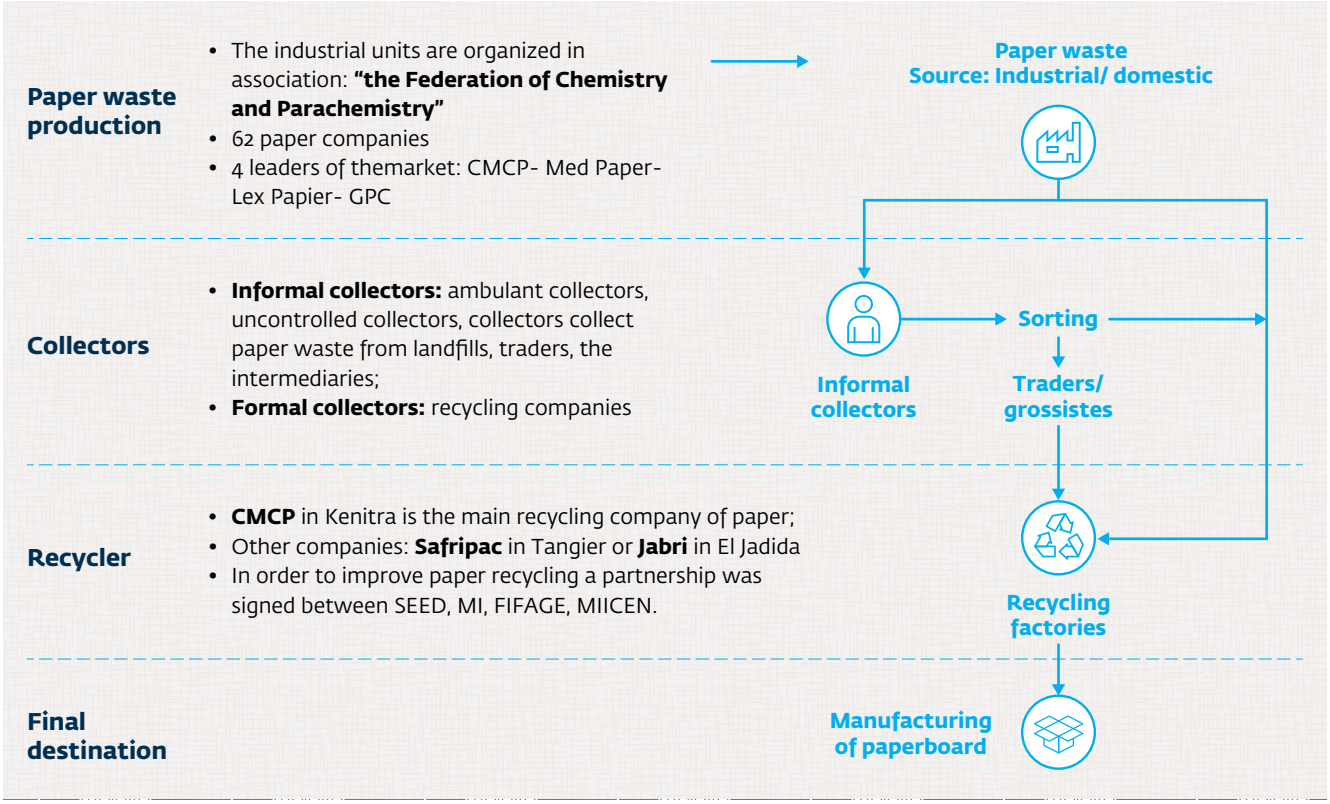
5.6.2.2 Paper waste management

Morocco produced an estimated 962,249 tons of recyclable paper material in 2015, with approximately 58 percent of paper waste coming from households. It is estimated that 262,486 tons was recycled, for an average recycling rate of 27 percent.

Figure 18 illustrates the paper waste value chain.

To promote paper recycling, a partnership was signed between the Ministry of Industry and Trade; the Federation of Forest Industries, Graphic Arts, and Packaging; and the Ministry of Energy Transition and Sustainable Development to strengthen and create a competitive paper industry in Morocco.

Figure 18: Paper Waste Value Chain



5.6.3 Waste Management within the TFZ

All companies in the Tanger Free Zone (TFZ) are aware of the challenges linked to waste management and recycling. Most are International Standards Organization 14001 certified, meaning that they manage their waste sustainably. Below are examples of how some types of waste are managed within the TFZ.

- **Wood:**
  In the TFZ, the wood waste loop is closed. Some recyclers collect wood waste from firms in the zone and remanufacture it into pallets. The residual wood from this operation is sent to a cement plant for incineration or to a biomass boiler.

- **Metals:**
  Metals require considerable energy for remelting. A closed loop exists through a recycler who treats all types of ferrous and non-ferrous metal waste, sorting at the source to save time and money and ensure quality.

- **Rubber:**
  A specialized company manages rubber. Waste is sent to a cement factory for incineration (Geocycle company of Lafarge-Holcim group). Because of quality concerns, industrialists do not use rubber waste (including their own). Once rubber is processed, it cannot be returned to its virgin state to make new rubber.

- **Plastics:**
  There is a company in the TFZ that collects plastic waste (polyethylene terephthalate) from the entire zone and recycles it into resins. Other recyclers collect other types of plastic waste, and some types go to controlled landfills.

- **Wastewater:**
  Treated water from the wastewater treatment plant is used for irrigation of the golf course. Tangier Med Utilities is looking to add tertiary wastewater treatment reach a quality that can be used by the industrial companies within their different processes.

5.7 KEY INSIGHTS FROM THE BENCHMARKING

The goal of benchmarking is to improve business models and generate new ideas for a textile recycling loop in the area of Tangier based on the experiences of other countries in creating sustainable textile recycling initiatives and building on national experiences of structuring waste collection systems to allow a recycling industry to emerge.

The Turkey NØW Project is the best example of financial institutions encouraging investment in and development of new technologies and helping transform the regulatory framework. Bangladesh Fashion Partnership and Cyclo Bangladesh are successful collection and recycling projects highlighting that partnerships between textile companies and recyclers is necessary to develop recycling practi where traceability is the key feature to ensure transparency and increase trust between all parties involved. The best examples of sorting are the Spanish initiatives involving automated sorting machines using near-infrared technology.

Based on national approaches, it is possible to have informal and formal recycling efforts occurring at the same time, although the formal sector takes a larger market share over time. The focus on industrial zones shows that it is possible for recyclers to work directly with zone operators, especially in zones where textile waste is not the main waste stream.

6. Traceability Measures and Waste Management Technologies

6.1 TRACEABILITY OVERVIEW

There are three types of traceability mechanisms.

1. **Off product:** An identifier is provided alongside the product at its place of origin and accompanies it going forward. Examples are certificates of authenticity and audit certificates.
2. **On product:** An identifier is affixed to the product at its place of origin and remains on it. It can be removed through physical force or a chemical process. Examples are serial numbers and embossed bank notes. Typical examples from the textile sector are barcodes and radio frequency identification tags.
3. **In product:** An identifier is embedded in the product at its place of origin and can typically be removed only by physically destroying the product.

6.1.1 Off Product: Blockchain

The use of blockchain identifiers tags are methods to connect the apparel supply chain with a real-time flow of data using a single, unalterable, transparent ledger. Each material batch is certified with a digital token, ensuring a unique digital identity for the material. Consumers enjoy greater security, because the life cycle of each garment is available online, from when and where it was designed to the first purchase and even resale. Advantages include providing full supply chain knowledge, authentication, and quantification. These methods are used in the previously identified projects: Bangladesh's use of the Reverse Resources software and the Sorting for Circularity project in India. The key disadvantages of this traceability measure are that it is costly and requires a long time to implement.

6.1.2 Off Product: Certificate of Authenticity (Manual Tracking)

Certificated of authenticity are the most cost-effective traceability method available. They are provided with each batch of textile waste that manufacturers sell to recyclers and with recycled products sold back to manufacturers. They Provide identification, proof of origin, quantification and are relatively easy to implement. The key issue with these certificates is that they are not tamper-proof.

6.1.3 On Product: Radio Frequency Identification Tags

RadioFrequency Identification (RFID) tags tag or smart labels replace more traditional paperwork. Unlike a physical barcode label, information can be stored throughout the life of the product.The type of information stored includes product origin and different locations of the various transformations along the value chain. It is an efficient tracking system for new textile products but not yet confirmed if it can be applied to recycled fibers. It has high implementation costs and requires the purchase of scanners in factories and adding tags to batches of fibers or other points of the transformation process (spinning, weaving, dyeing, etc.)

6.1.4 On Product: Dyes or Particles

This traceability measure is achieved by adding colored or invisible dyes or particles to fibers authenticates fibers and provides proof of origin. It is expandable but not tamper proof and does not provide full supply chain knowledge.

6.1.5 In Product: Deoxyribonucleic Acid Tracers

This traceability measure allows full identification, proof of origin, and authentication and is tamper proof. It does not provide all the information on the supply chain but can trace source of fiber and fabrics which is an advantage to track recycled material. The implementation costs are high and require capital costs for labs specific training to use this new technology. There are two types of deoxyribonucleic acid (DNA) tracers:

- Naked DNA tracers: Synthetic DNA segments are placed on or under the surface of a product at the nano level and can be read by taking and analyzing samples (e.g., via swabs) from the treated surface.
- Encapsulated DNA tracers: Synthetic DNA segments are encapsulated at the nano level into a carrier medium and placed—similar to the naked version—on or under the surface of a product. As above, they then can be read by taking and analyzing samples (e.g., via swabs) from the treated surface.

Case studies include the Egyptian Cotton Project and CYCLO Company in Bangladesh.

6.1.6 In Product: Isotopes

Cotton from different growing regions processed into finished goods can be differentiated and traced as to their origin by measuring the isotopes that naturally occur through the growing environment. Detected isotopes produce a one of-a-kind origin fingerprint. Fingerprinting with stable isotopes can determine the provenance of a cotton product.

6.2 TRACEABILITY PROJECTS

6.2.1 Haelixa (Pakistan)

Haelixa has collaborated with Soorty, a Pakistani denim manufacturer, to make recycled cotton traceable. Using Haelixa's DNA marker, virgin or recycled fibers can be traced in finished apparel. The marker is dissolved in liquid and applied to textile waste before it is mechanically recycled in a spinning mill. Spot checks are done of intermediate products, as well as tests of the final garment, to prove that the product contains the recycled cotton. The test is based on highly scalable polymerase chain reaction technology that is 100 percent reliable and has forensic validity. Verification is performed using quantitative polymerase chain reaction. The technology works as a key-lock system that requires knowledge of the DNA code to detect it. The results are then uploaded into an existing enterprise resource planning system, or customized digital interface.

6.2.2 In Product: CertainT

Applied DNA Sciences is expanding its CertainT traceability technology to include authentication of recycled polyester; until now, CertainT has mainly been used to authenticate cotton and polyester. The tags have three technology pillars: tag, test, track.

1. **Tag:** The unique molecular tag is added to raw materials, finished products, labels, and packaging.
2. **Test:** Material and product integrity is verified throughout the supply chain by confirming the presence of the unique molecular tag.
3. **Track:** All data associated with tagging and testing activities are captured, facilitating understanding of a company's supply chain dynamic.

The tag can be used on or in recycled materials, including polymers such as polyethylene terephthalate, polypropylene, polyethylene, and acrylic. This technology is being used by the U.S. to identify product origin in accordance with the **Uyghur Forced Labor Prevention Act** which prevents all imports that originate from China's Xinjiang Uyghur Autonomous Region from entering the United States.

6.2.3 Off Product: Reverse Resources Digital Tracking

Reverse Resources is software as a service that provides a digital platform to track materials in terms of collection, quality, description, and delivery. Digitizing waste flows enables the entire actors of the supply chain such as manufacturers, waste handlers and recyclers to track, trace, and valorize textile waste. it provides infrastructure that makes it easy to expand circular supply chains and recycling systems. This measure is used in Bangladesh's Circular Fashion Partnership and India's Sorting for Circularity project.

6.2.4 On Product: IN-Code Technologies

Already operating in six regions, including in India, IN-Code offers in-product and on-product markers, including near-field communication smart tags (E-codes), edible biomarkers (IN-Codes), and optical fingerprints (Li-codes [visible fluorescents]). These tags are embedded into a garment, which has a unique identification code that can be scanned using a mobile phone and links with the online database data stored in the code. The near-field communication tags have shown that it is possible to track organic cotton from the farm to retail.

6.3 TRACEABILITY RESEARCH

The Fashion for Good traceability lab compared traceability mechanisms in a field study. Participants included Haelixa, Tailorlux, IN-Code Technologies, and CoreBiome. Haelixa provides product markers based on DNA; Tailorlux provides markers based on fluorescent viscose fibers; IN-Code provides markers based on near-field communication smart tags, edible biomarkers, and optical fingerprints; and CoreBiome provides origin identification based on naturally occurring microbiomes and artificial intelligence analysis.

The key findings of this research are:

- DNA, fluorescence, and biomarkers were detected at each stage of the supply chain.
- Blockchain technologies will create greater visibility for fashion industry actors, who often only have insight into their tier 1 suppliers. This solution can help them understand their supply chain and help consumers understand the origin of their organic cotton products and their impact on the lives of farmers around the world.
- The Haelixa, Tailorlux, and IN-Code tracers were verified along the supply chain.
- A key to success is cross-sector collaboration of multiple stakeholders from different parts of the supply chain.

The Lifting the rug report: How Traceability in Textiles Improves Financial and Sustainability Performance has three key takeaways:

1. Investors should not tolerate lack of traceability—for sustainability, regulatory, and economic reasons. Regulation is making traceability a requirement, with the European Union leading the way. Investors should demand full traceability from companies as part of their fiduciary duty.
2. Focusing on the costs of traceability systems ignores the profit enhancement it delivers (net profit enhancement of 3-7 percent), as well as environmental, social, and risk-mitigation benefits.
3. Tools for companies to have full traceability through their supply chain exist; “It’s not possible” is no longer a valid excuse. No company should be able to promote its sustainability credentials without proof of full traceability, which may involve some transparency measures

6.4 TRACEABILITY SUMMARY

There are many start-ups, projects, and programs for in-product traceability mechanisms, because traceability offers more opportunity for technology innovations than off- or on-product mechanisms. Off-product traceability is straightforward and does not require innovative technologies, so it is the easiest, most cost-effective method of integrating traceability into a supply chain. On product is similar but still has room for innovation regarding the tags applied to products. Digital tracking is a large area for innovation, with blockchains increasing in popularity.

The most common traceability mechanism in use today in the textile sector is manual tracking and certificates of authenticity, probably because most manufacturers keep track of the composition of their materials already, so it is easy to produce a label or certificate that verifies this.

6.5 TEXTILE SORTING TECHNOLOGIES

6.5.1 Process

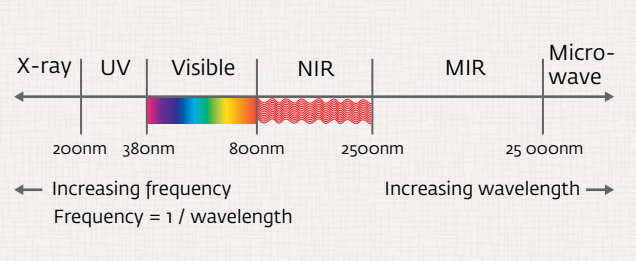
Most equipment that enables textiles to be recognized is based on the spectroscopy principle, which works as follows:

1. An electromagnetic wave is sent to the sample to be analyzed.
2. The wave and the sample's chemical structure interact (e.g., molecule, atom, bonds).
3. The wave is measured after having interacted with the sample.
4. A spectrum is produced.

The spectrum represents the sample's chemical signature, so the spectrum's comparison of an item's unknown composition with a reference spectra database of pre-recorded samples enables the composition of the item analyzed to be determined.

Spectroscopy using near-infrared waves appears to be the most relevant for use in textile recognition. Near-infrared analysis is a spectroscopic technique that uses the naturally occurring electromagnetic spectrum. The near-infrared region is the area of the spectrum defined by wavelengths between 700 nm and 2,500 nm as shown in Figure 19.

Figure 19: Near-Infrared in the Electromagnetic Spectrum



The working principle can be defined as follows:

- Near-infrared light is directed onto a sample.
- The composition of the sample modifies the light, and this modified light is detected.
- The spectral modifications are converted into information about the composition of the sample.
- These conversion algorithms are called "calibrations."

Near-infrared spectroscopy advantages:

- Can determine the chemical composition of textiles because materials can be differentiated using it.
- Is less expensive than other spectroscopic technologies.
- Is a mature technology.
- Is a rapid, nondestructive analytical technique.
- Is optimal for continuous quality control.

Near-infrared spectroscopy drawbacks:

- Near-infrared spectroscopy analyzes only a material's surface. Nonuniform three-dimensional objects may be wrongly identified.
- Dark pigments may hinder or make material detection impossible by absorbing all infrared waves.

6.5.2 Key Data for Business Model Development

- Cost of NIR Spectrometer: 15-25 thousand Euros.
- Cost of Optical sorting machine: 150-200 thousand Euros.
- The main suppliers of equipment for recognition and sorting technologies that can be applied to textiles are: Iosys/GUT, LLA Instruments, Pellenc ST, Spectral Engines, TOMRA,Valvan.

7. Business Models

Structuring waste collection systems is critical to successful implementation of circularity in the textile sector. Given the field activities conducted for this study and previous experiences of the consulting team, three business models were selected for further analysis:

1. Collecting all waste from textile companies, sorting the waste, and sending the different types of waste to the appropriate recyclers. This includes paper and cardboard, wood, and plastics but excludes organic waste, which the municipality or zone operator usually handles.
2. Collecting, sorting, and aggregating mixed textile waste.
3. Collecting cotton waste.

7.1 BUSINESS MODEL 1: COLLECTING ALL WASTE

This first business model is the easiest to implement because it is easier for textile operators to have as few service providers as possible. It is common practice in industrial zones to have one collector take all waste and handle it according to national regulation. This is usually a paid service where the waste generator pays the collector, in which case the waste is obtained for free. In some cases, it is possible that the textile operator already sells some waste, but in the proposed scenario, it is assumed that the collector collects all types of waste. The only waste that is not accounted for in this model is organic waste generated from the administrative areas of businesses that tend to have small kitchens for employees to use during breaks.

The main features and key assumptions used in the risk analysis and financial assessment of the potential investment are as follows:

- Types of waste collected: paper and cardboard, wood, plastics, textiles.
- Capital expenditures: land acquisition and construction of warehouses.
- Size: quantity of waste is based on TFZ waste generation, and textile waste is based on 20 percent of total waste available.
- Operational expenses: transportation, human capital, energy consumption.

7.2 BUSINESS MODEL 2: MIXED TEXTILE WASTE COLLECTION

The second model focuses on mixed textile waste. Collection will focus on all types of textiles produced. It is assumed that the collection service will be partial, only collecting textile waste and no other waste generated by the companies, and that the dedicated collection platform can serve as a collection point for informal collectors or small collectors that do not have aggregation or recycling capability. The textiles will be sorted and sold to the existing recycling companies.

The main features and key assumptions used in the risk analysis and financial assessment of the potential investment are as follows:

- Types of waste collected: mixed textiles, including technical textiles used in the auto industry.
- Capital expenditures: land acquisition, construction of warehouse, equipment costs.
- Size: 20 percent of total available waste in Tangier area.
- Operational expenses: transportation, human capital, energy consumption, raw materials.

7.3 BUSINESS MODEL 3: TARGETED COTTON WASTE COLLECTION

Business model 3 is based on the ability to secure cotton waste directly from textile companies. Two proposals will be made to either provide a dedicated bin for the company to place 100 percent cotton waste or provide the bin and an operator to support in the identification and collection of cotton waste. The idea being that the operators can cover several companies in the same area and make sure that the cotton produced is placed in the bins. This is important in the first phases of implementation, during which textile companies will change their behavior toward separation and collection of cotton waste.

The main features and key assumptions used in the risk analysis and financial assessment of the potential investment are as follows:

- Types of waste collected: cotton only.
- Capital expenditures: land acquisition, construction of warehouses, equipment costs.
- Size: 20 percent of total available waste in Tangier area.
- Operational expenses: transportation, human capital, energy consumption, raw material.

7.4 FINANCIAL ANALYSIS

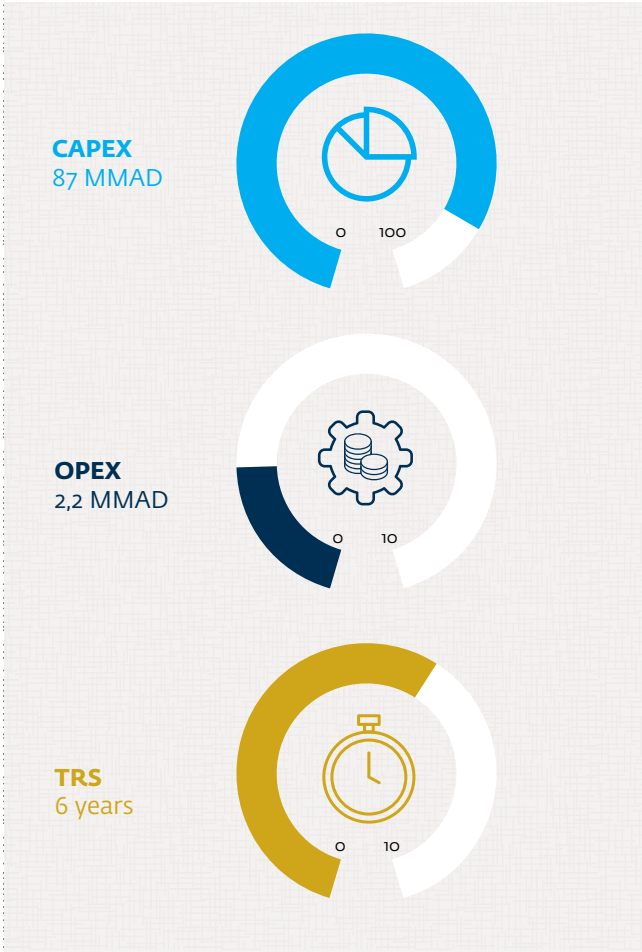
For each of the business models for collection and sorting, a simple financial analysis was conducted. The total investment cost was assessed including the cost of the necessary equipment, warehouse, transportation to start the operations. In addition, key operational costs such as labor, purchase of raw materials and energy costs were estimated. Finally, an estimate of potential revenue was conducted to calculate simple payback period. The following tables and figures summarize the results of the analysis for all three business models:

Table 3: Summary of Financial Data for all Business Models

	BM1	BM2	BM3
Capex (MMAD)	87	52.5	6.8
Opex (MMAD)	2.2	5	4.4
SPBP (years)	6	5	2.3

The first business model has the highest capital expenditure as it involves collecting all types of waste including non-textile waste and necessary sorting equipment. The operational costs are lower since most companies will pay for their waste to be removed and therefore the business does not include paying for the waste. Additional revenue from the waste management services was not considered in the calculations.

Figure 20: Financial Data for Business Model 1



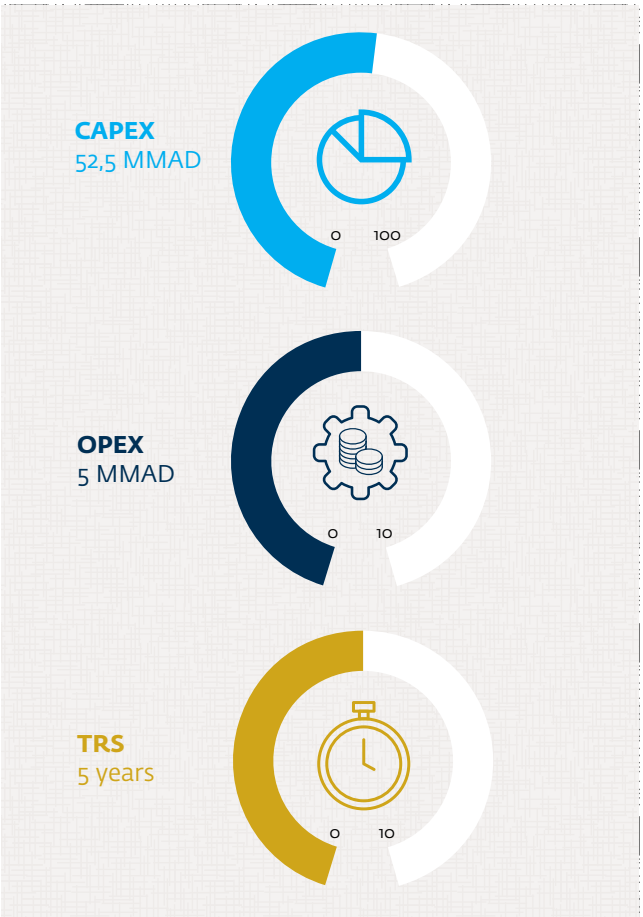
The main variables affecting the business decision for this business model are the quantities of waste that can be obtained because of the difficulty in obtaining and the sale price of the waste due to high variability. Figure 21 shows the sensitivity of the simple payback period linked to the variation of these two variables.

Figure 21: Sensitivity Analysis of Business Model 1

Quantity of textile waste (t/year) \ Sale price of textile waste (MAD/t)	1350	1500	1667	1834	2017
5103	13.89	12.39	11.05	9.98	9.02
5670	12.49	11.14	9.94	8.98	8.11
6300	11.23	10.02	8.94	8.07	7.29
6930	10.20	9.10	8.12	7.33	6.63
7623	9.27	8.27	7.38	6.66	6.02

The second business model is dedicated to mixed textile, with a capital expenditure that includes a warehouse large enough to be able to collect large quantities of waste as well as high tech equipment that can sort textiles by type and color.

Figure 22: Financial Data for Business Model 2



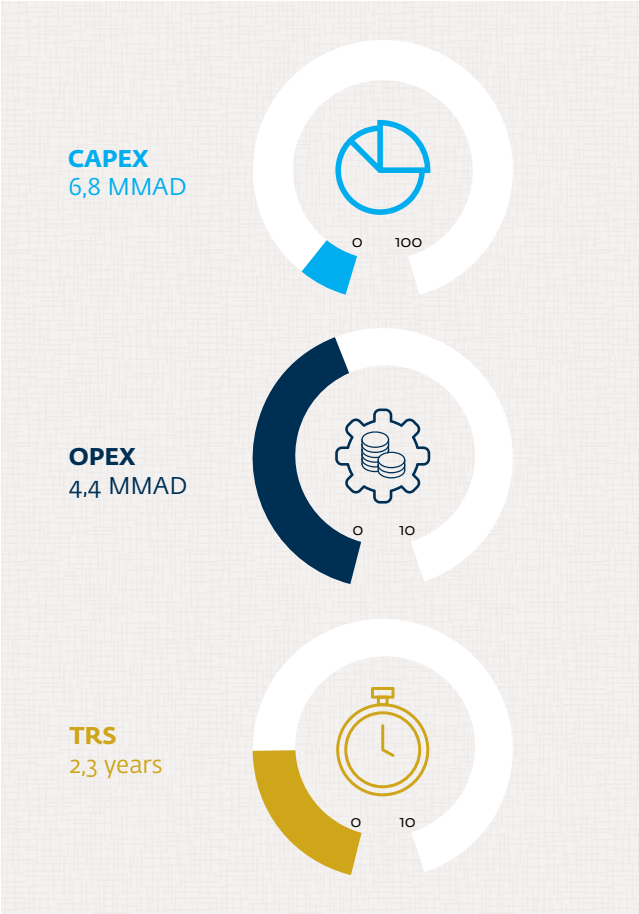
The sensitivity analysis of business model 2 was based on the variation in quantity and sale price of waste (Figure 23).

Figure 23: Sensitivity Analysis of Business Model 2

Quantity of textile waste (t/year)	Sale price of textile waste (MAD/t)				
	1350	1500	1667	1834	2017
5103	17.58	13.99	11.41	9.63	8.22
5670	15.17	12.18	9.99	8.47	7.25
6300	13.16	10.64	8.78	7.47	6.41
6930	11.63	9.45	7.82	6.68	5.75
7623	10.30	8.42	6.99	5.98	5.16

The final business model dedicated to collecting cotton waste requires less initial investment costs since the sorting will be done mainly at the collection points (textile companies) where dedicated bins and personnel will be assigned to sort the waste and only collect the cotton waste. This model will require simpler infrastructure.

Figure 24: Financial Data for Business Model 3



The sensitivity analysis of business model 3 was based on the variation of quantity and sale price of waste (Figure 25). For this option, the project will not be viable with a sale price less than 3.6 dirhams/kg and will not be able to operate with quantities less than 1400 tons per year.

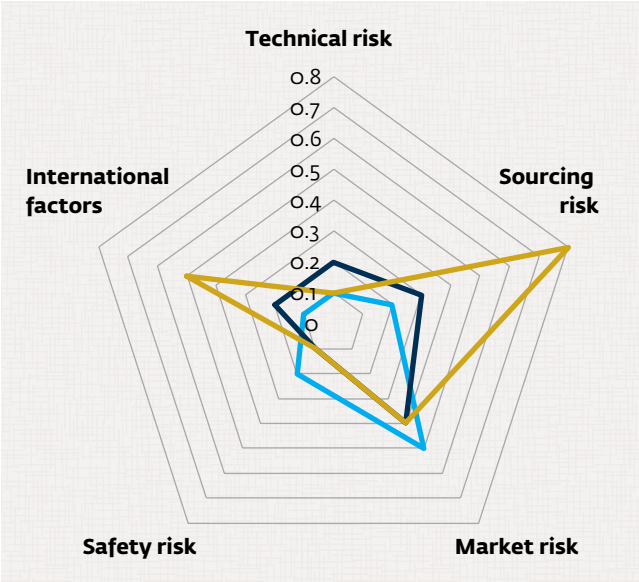
Figure 25: Sensitivity Analysis Business Model 3

Quantity of textile waste (t/year)	Sale price of textile waste (MAD/t)				
	3240	3600	4000	4400	4840
1134	-41.65	33.32	11.11	6.66	4.63
1260	-899.65	16.97	7.96	5.20	3.76
1400	41.10	10.99	6.06	4.18	3.12
1540	20.09	8.12	4.89	3.49	2.66
1694	12.86	6.31	4.03	2.96	2.29

7.5 RISK ANALYSIS

A risk analysis was conducted for all three models based on five criteria: technical risk, sourcing risk, market risk, safety considerations and international factors. The technical risk includes technology maturity and complexity; sourcing risk is related to waste availability and cost variation; market risk considers sale of recovered material into the appropriate recycling chains; safety is linked to types of waste handled and the wellbeing of the employees; international factors include any potential threats from changing international regulations. Each of these risks was assessed based on probability of occurrence and severity of the consequences if the risk were to happen and were evaluated on a scale of 0-1 where 1 is very high.

Figure 26: Risk Assessment of the Business Models



For business model 1, the key risks are linked to the multitude of products diversification of the collected waste and the difficulty of managing all of the waste streams in terms of sale to the appropriate off-takers. For business model 2, the market for all the various recycled products is the highest risk since there are some materials that are difficult to recycle. The last business model is more impacted by sourcing risk and international factors since it relies on one type of waste only and is highly dependent on orders from the fashion industry in Europe using cotton for their garments.

7.6 ONLINE PLATFORM

7.6.1 Digitization: Opportunity to Build Textile Circularity

A digital platform could help circular system actors find required services and increase textile circularity, enabling materials to be tracked in terms of collection, quality, description, and delivery to recyclers.

The platform would enable circular online commercial collaboration between the fashion industry, recyclers, and manufactures. One platform that has launched in Bangladesh is the Reverse Resources platform. It is geared at collectors, sorters, and pre-processors to facilitate textile-to-textile recycling. It maps the segregated waste and connects actors, matching waste streams to recycling technologies. The platform serves 51 recyclers, 19 waste handlers, and 945 manufacturers. The platform has solved the problem of difficulty to access cotton waste, incomplete waste data, and inflated prices that current waste handling and trading practices cause.[25] The platform removes market barriers, shortens supply chains, and thereby increases value. It creates competitivity in terms of the cost of textile-to-textile recycling and supports the circular economy.

25 https://reverseresources.net/

Annex 1: Surveys

TEXTILE COMPANIES

1. General

- Company Name: _____
- Location: _____
- Activities: ☐ Spinning ☐ Weaving ☐ Sewing ☐ Other: _____
- Annual production volume: _____
- Market (clients): ☐ National ☐ International
- Respondent's name: _____
- Position: _____
- Telephone number or email address: _____

2. Textile waste production

- Cutting waste:

Composition	100 percent cotton	Cotton + polyester	Other
Quantity generated (tons/year) per color	White: Black: Ecru: Other:	White: Black: Ecru: Other:	White: Black: Ecru: Other: ... ...
Waste rate compared to raw material			
Destination (collector type)			
Selling price / Price to pay to get rid of textile waste(-)			

- Other types of waste:

Type	Spinning waste	Weaving waste	Over-production	Dead stock	Non-compliant products
Quantity generated (tons/year) by composition	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other: ... ...
Ratio /raw material					
Destination					
Selling price / Price to pay to get rid of textile waste(-)					

3. Textile waste management

- Textile waste treatment
  ☐ Sorting by type and color ☐ bagging of waste ☐ baling of waste ☐ no treatment ☐ Other: _____
  If textile waste is not treated, why? _____

- Is there any traceability system to identify the waste: ☐ Yes ☐ No
  If yes, which traceability system do you use? _____
  If no, why don't you use one? _____

- Does your company create an annual waste report for the Sustainable Development Department? _____
- Is it possible to give us a sample of waste? _____
- Do you keep an annual waste management register in accordance with law 28-00? ☐ Yes ☐ No
- When you sell a waste to a recycler, wholesaler, or recycling company, do you have a certificate of traceability:
  ☐ Yes ☐ No
- Do you have customers who require a waste separation/collection procedure? ☐ Yes ☐ No
- Is all the textile waste collected and disposed of with other waste? ☐ Yes ☐ No
- If there is a possibility to sell the waste, are you interested in investing in the sorting and storage of 100 percent cotton waste? ☐ Yes ☐ No
- From what price you are ready to sell the waste? _____ (dirhams/kg)

COLLECTORS AND AGGREGATORS

1. General

- Actor Status:
  - ☐ Formal recovery company
  - ☐ Informal
  - ☐ Intermediary
  - ☐ Wholesaler
  - ☐ Other: _____
- Company name: _____
- Location: _____
- Area covered: _____
- Respondent's name: _____
- Position: _____
- Telephone number or email: _____
- Resale relationship: committed to one customer, if so why? Because of financial loans, favorable selling….? _____
- Average monthly revenue: _____
- Collection area: fixed, variable…? _____
- Number of working days per week: _____
- Average volume collected per week or/month: _____
- Activity type: ☐ Collection ☐ Sorting ☐ Recycling (waste treatment)

2. Identification of collected textile waste

- Cutting waste:

Composition	100% cotton	Cotton + polyester	Cotton + viscose	Cotton + linen	Other mixed waste (to be identified)
Quantity recovered (tons/year) by color	White: Black: Ecru: Other: … … …	White: Black: Ecru: Other: … … % cotton: % polyester:	White: Black: Ecru: Other: … … % cotton: % viscose:	White: Black: Ecru: Other: … … % cotton: % linen:	White: Black: Ecru: Other: … … % cotton: % other fiber:
Sources (supplier type: textile industrial unit, informal collector…)					
Number of suppliers					
Frequency of collection by supplier					
Destination (clients + cities)					
Sector destination (e.g., clothing, furnishings…)					
Purchase price per kg or bulk					
Selling price per kg					

- Other types of wastes

Type	Spinning waste	Weaving waste	Overproduction	Dead stock	Customs seizure	Production defect
Quantity generated (tons/year) by composition	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other:	100% cotton: Cotton + polyester: Other: ... ...
Cotton quality	Ecru: Washed: Contaminated by impurities:	Ecru: Washed: Contaminated by impurities:	Ecru: Washed: Contaminated by impurities	Ecru: Washed: Contaminated by impurities:		
Sources (supplier type)						
Number of suppliers						
Frequency of collection by supplier						
Destination (clients + cities)						
Sector destination (e.g., clothing, furnishings...)						
Purchase price / price of collection service						
Selling price						

3. Textile waste management

- Describe the status of the waste collected: sorted in bulk baled other: _____
- Treatment of collected waste: ☐ Sorted by color ☐ baled ☐ no treatment ☐ other:_____
  If the waste is not treated, why? _____
- Is there any traceability system to identify the waste: ☐ Yes ☐ No
  If yes, which traceability system do you use? _____
  If no, why don't you use it? _____
- Mode of transport used: ☐ truck ☐ motorbike ☐ other: _____
- Transportation conditions: ☐ bulk ☐ baled ☐ other: _____
- Storage capacity: _____
- Storage conditions: ☐ bulk ☐ baled ☐ other: _____
- Average transport distance: _____
- What are the challenges/problems you have faced and your suggestions for structuring the textile waste collection value chain? _____
- Is it possible to give us a sample of waste? _____

Annex 2: Round Table Participants

Company	Contact
AMITH	Yassine Arroud
AMITH	Hassan Hatimi
IFC	Eleonore Richardson
IFC	Txomin Goitia
IFC	Ghita Hanane
Africa Climate Solutions	Hiba Rizk
Africa Climate Solutions	Othman Mefdaoui
Africa Climate Solutions	Mehdi Hssein
Africa Climate Solutions	Manel Hessi
CRI Tanger	Abdelilah El Hadine
CGEM	Benmokhtar
TMSA	Ijlal El Khattabi
AZIT	Ammar Chammaa
Conedmar (groupe Wolkat)	Zakaria Ouriachi
Lenzig (en ligne)	Dorner Andreas
Inditex (en ligne)	Felix Poza Pena
Hallotex	Elharit Gourdioui
Reciclados	Souhaib A.
Erum	Jose Carlos Mulero
Medi Recylage	Mohamed Zahime

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