Circularity in the Jordanian RMG Sector

A Study on Garment Waste Materials Reduction and their Revalorisation Potential

Implemented by

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In cooperation with

adelphi

Senture

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BMZ	Federal Ministry for Economic Cooperation and Development
CW	Capacity Works
DC	Development Cooperation
FTA	Free Trade Agreement
GAIN	Green Action in Enterprises
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HIE	Al-Hassan Industrial Estate
HS	Harmonized System
MAP	Promotion of Multi-Stakeholder Projects for Sustainable Textile Supply Chains
MFA	Material Flow Analysis
MoEnv	Ministry of Environment
PST	Partnership for Sustainable Textiles
QIZ	Qualified Industrial Zone
RMG	Ready-Made Garment
SME	Small and medium-sized enterprises
SV	Sector Project
TORs	Terms of reference
WP	Work Package

الملخص التنفيذي (English version on page 7)

ينتج قطاع صناعة الملابس الجاهزة في الأردن في المناطق الصناعية مثل مدينة الحسن الصناعية كميات تعد كبيرة من النفايات الصلبة (على شكل قصاصات ملابس)، و يتم التخلص منها حاليا في مكبات النفايات العامة.

و لهذا السبب قامت مؤسسة أبحاث أديلفي الألمانية من خلال جهد مشترك لمعالجة هذه المشكلة بالعمل مع GIZ نيابة عن الوزارة الفيدرالية الألمانية للتعاون الاقتصادي والتنمية (BMZ) على تحديد الفرص المتاحة لتقليل نفايات المنسوجات والملابس. و في نطاق هذا العمل ، تم تقييم البيانات التي تم جمعها حول نفايات صناعة الملابس الجاهزة في مدينة الحسن الصناعية. ,و بناءاً على هذه المعلومات، تمت دراسة قائمة حلول اقتصاد دائري على مستوى المصنع والقطاع مبدئياً لمنع إنتاج النفايات ولإعادة تقييم النفايات كهدف ثانوي. تم خلال هذا المشروع جمع بيانات كمية ونوعية من تسعة من أصل إحدى عشر من أكبر مصنعي الملابس الجاهزة في المنطقة الصناعية إضافة إلى مقابلة ثلاث جهات وثيقة الصلة بالقطاع من طرف مؤسسة إدارة المدن الصناعية. و قمنا أخيراً بإجراء تحليل تدفق للمواد (MFA) في عملية تصنيع الملابس الجاهزة (انظر الشكل أدناه).

مدينة الحسن الصناعية

تستضيف مدينة الحسن الصناعية العديد من قطاعات التصنيع، مثل صناعة الملابس الجاهزة والأغذية والأدوية وصناعة المواد الكيميائية وتصنيع البلاستيك. ويوجد حوالي 108 مصانع تعمل داخل مدينة الحسن الصناعية.26 من هذه المصانع تعمل في قطاع تصنيع الألبسة الجاهزة وينتج عنها ما يقدر بنحو 35000 طن من الألبسة الجاهزة سنويًا (2021). يتم إرسال النفايات الناتجة من تصنيع الألبسة الجاهزة حاليًا إلى مكب نفايات الأكيدر.

الإطار السياسي

في تشرين الأول من عام 2021 أصدرت وزارة الإدارة المحلية قراراً بعدم السماح لمكب الإكيدر بقبول نفايات المنسوجات من مدينة الحسن الصناعية، حيث سيتم إعادة تأهيل الأرض المستخدمة للتخلص من نفايات صناعة الأنسجة. ولكن هذا القرار لم يدخل حيز التنفيذ وتم تخطيه. يستمر المكب في استقبال نفايات صناعة الألبسة الجاهزة وغيرها من النفايات الأخرى من مدينة الحسن الصناعية إلى الآن. ولا يوجد حالياً أي إجراء شامل متخذ للحد من النفايات ولا يمارس القطاع مبادئ الاقتصاد الدائري في مدينة الحسن الصناعية، وتعتبر الجهود المبذولة للحد من كمية النفايات ضئيلة، فردية وناتجة عن دافع خفض الكلفة.

سلسلة القيمة

تتبع معظم المصانع نفس الخطوات تقريباً خلال الإنتاج، بدءًا من استلام وفحص لفات القماش، التي يتم وضعها بعد ذلك في المستودع، ثم قصها إلى قطع مختلفة، ثم يتم بعد ذلك تجميع هذه القطع وخياطتها معًا، قبل إجراء فحص الجودة وتغليفها كملابس جاهزة من أجل شحنها للعميل.

كميات النفايات

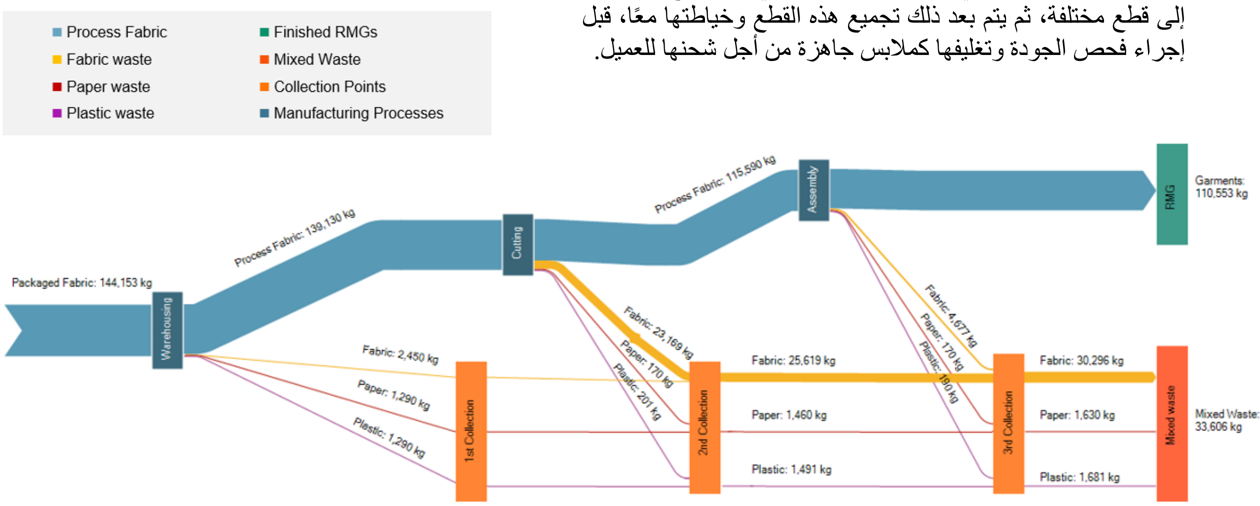
تبين من خلال مرحلة جمع المعلومات أن قطاع صناعة الملابس الجاهزة ينتج عنه ما يقدر ب 33.6 طن من نفايات الأنسجة يومياً، وذلك طبقاً لأحدث البيانات المتوفرة. وينتج مصنع الملابس التقليدية، والذي يعد الأكبر في القطاع ما يقدر ب 16.8 طن من نفايات الأقمشة التي يتم التخلص منها بشكلٍ يومي.

تكوين النفايات

بناءً على المعلومات التي تم جمعها وجد أن النفايات الناتجة عن مصانع الألبسة الجاهزة تتكون من 90.2٪ من القماش، بينما يشكل البلاستيك والورق حوالي 5٪ لكل منهما. كم يمكننا افتراض أن نفايات النسيج تتكون في الغالب من 100٪ قطن، أو 100٪ بوليستر أو مزيج بين بوليستر / قطن أو بوليستر / مواد تركيبية أخرى بنسب مختلفة (على سبيل المثال 45/55، 35/65 أو 20/80). ولذلك يجب القيام بتحليل مفصل لهذه النفايات.

خطوات التصنيع ذات الصلة

تبين لنا أيضًا أن مرحلة القطع تنتج حوالي 70 ٪ من إجمالي نفايات الأقمشة. في حين تشكل خطوتي التخزين والتجميع ما نسبته 15٪ من إجمالي حجم النفايات. يمكن تقدير حجم الإنتاج اليومي من الملابس الجاهزة بما يتراوح بين 105 و110 طن في اليوم. كما يقدّر العدد الإجمالي لعدد القطع المنتجة بأكثر من 600.000 قطعة في اليوم.



من أجل التطرق إلى إمكانية الحد من النفايات وإعادة تقييم حجمها، قمنا بعمل دراسة منهجية عن خيارات اقتصاد دائري في ثلاث مناطق في المصنع خلال عملية التصنيع وفي ثلاث مناطق أخرى على مستوى القطاع. وبناءاً على ذلك تم تحديد 12 خيارًا دائريًا (انظر الشكل أدناه). ويعتمد اختيار الخيارات الممكنة على عدة عوامل مثل إطار السياسة الداعمة، وتوافر وإمكانية الوصول إلى الموارد المالية، ومجموعات المهارات وأصحاب الخبرة، وحال مزودي التقنيات اللازمة.

على مستوى المصنع

أولاً، لتقليل نفايات التصنيع، يُقترح استخدام جهاز قص أكثر كفاءة في استخدام المواد يعمل على تحسين إنتاج النفايات على مستوى متوسط كحل تقني. ومع ذلك، سيتطلب هذا أيضًا موارد مالية وقدرات تقنية.

ثانيًا، تنفيذ عمليتي الجمع والفصل لإعادة التدوير حيث يشكل الجمع والفصل إجراءً مهمًا للتطبيق والذي يمكن أن يكون فعالاً في استعادة المواد والحد من النفقات في المستوى المتوسط ، مع الأخذ في الاعتبار أن الفصل في هذه المرحلة سيتم يدويًا.

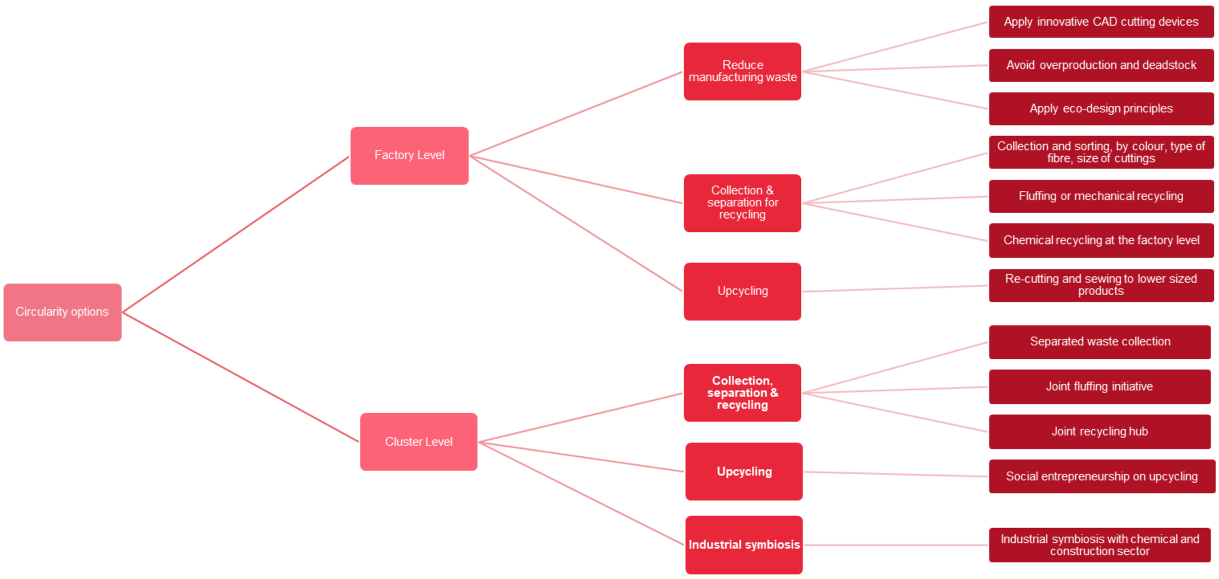
أخيرًا، إعادة التدوير للأفضل. فعلى سبيل المثال عن طريق إعادة قص وخياطة قطع القماش غير القابلة للاستخدام في منتجات أخرى والذي يعد أمراً مجدياً من ناحية مادية، لأنه لا يتطلب سوى تعيين موظفين إضافيين لهذه المهمة. وقد لا تكون هذه العملية فعالة من حيث الوقت بشكل خاص، ولكنها قد تجلب فرص عمل جديدة.

على مستوى القطاع

أولاً، لتنفيذ عمليات الجمع والفصل وإعادة التدوير، يجب أولاً إنشاء آلية واضحة لجمع النفايات. وقد يكون أحد الحلول المجدية اقتصاديًا هو جعل خطوة أنتاج الزغب خطوة مشتركة تطبق على كافة نفايات النسيج التي تم فرزها أوعلى الأقل على عددٍ من شركات النسيج المتعددة المتواجدة في مدينة الحسن الصناعية. قد يتم إنشاء خيار آخر لمحور إعادة تدوير مشترك حيث يتم جمع النفايات من جميع المصانع وفرزها من أجل إعادة تدوير النسيج إلى خيوط.

ثانيًا، يمكن أيضًا تنفيذ إعادة التدوير للأفضل على مستوى القطاع، من خلال تعزيز ودعم مشاريع ريادة الأعمال الاجتماعية من أجل إعادة التدوير للأفضل داخل القطاع.

أخيرًا، إنشاء نظام تعايش صناعي، من الضروري لمصانع إنتاج الألبسة الجاهزة تحديد قطاع أو حتى عدة قطاعات مناسبة مثل قطاع مواد البناء، بحيث يمكن إنشاء تبادل منتظم للمواد (نفايات الأقمشة) بينهم.



الخطوات المقبلة

سيتم خلال المراحل المقبلة من المشروع تقييم وبناء الجدوى الاقتصادية للحلول المقترحة ومناقشاتها مع أصحاب المصلحة، كما سيتم توفير دعم لبناء القدرات في القطاع ومناقشة السياسات الاطارية التي تحتاجها الحلول المقترحة لتدخل حيز التنفيذ

Executive Summary

In Jordan, the production of ready-made garments (RMG) in industrial zones such as Al-Hassan Industrial Estate (HIE) results in considerable amounts of solid textile waste that are presently disposed of in municipal landfills.

In a joint effort to address this issue, adelphi on behalf of the GIZ, is working on identification of opportunities for the minimisation of textile and garment waste. In the scope of this work, data on RMG waste from the HIE was assessed. On this base, a list of circularity options at the factory and cluster level were explored firstly for the prevention of waste, and secondly for revalorisation of the waste. Quantitative and qualitative data was collected from nine out of the eleven biggest RMG manufacturers in the estate as well as three other HIE management stakeholders through interviews. Additionally, a Material Flow Analysis (MFA) was conducted (see figure below).

THE ESTATE

HIE hosts several manufacturing sectors including RMG, food, pharmaceuticals, chemicals industry and plastic manufacturing. There are around 108 factories operating in HIE. 26 of them are operating RMG factories producing an estimate of 35,000 tonnes of RMG annually (2021). The collected waste is currently sent to the Al-Ekeider landfill.

POLICY FRAMEWORK

As of October 2021, the Ministry of Local Administration announced that Al-Ekeider Landfill will no longer accept textile waste from HIE, as the land used for textile waste disposal will be rehabilitated. However, this decision was overruled again, and the landfill continues to receive RMG and other waste from HIE. Existing waste minimization and circular economy engagements at HIE are minimal, driven mostly by cost reduction.

VALUE CHAIN

Most of the factories follow the same production processes, starting from the delivery and acceptance of fabric rolls, which are then put into the warehouse, before they are cut into different pieces. These pieces are then assembled and sewed together, before a quality check is conducted and the RMG is packaged for final dispatch.

WASTE AMOUNT

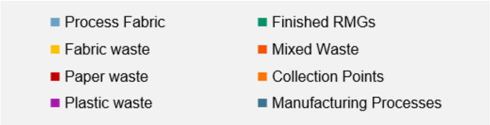
The data collection as part of this study reveals that a total of 33,6 tonnes of waste is created daily in the cluster by RMG factories according to current data. The biggest factory, Classic Fashion (CF) accounts for 16,8 tonnes of the waste disposed per day.

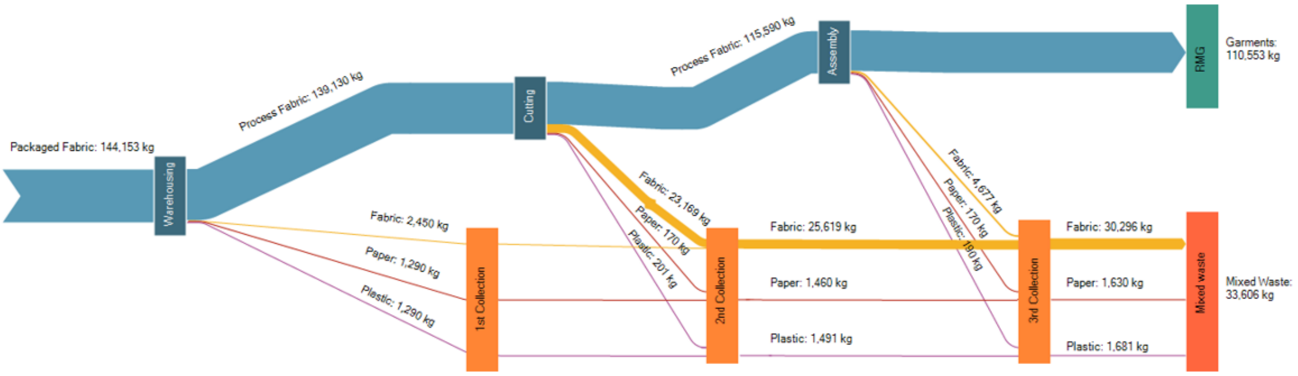
WASTE COMPOSITION

Based on the survey it was found that the generated waste from RMG factories consists of 90.2% of fabric, while plastic and paper make up for around 5% each. It can be assumed that the fabric waste consists mostly of 100% cotton, 100% polyester or blends between polyester/cotton or polyester/other synthetics in different ratios (e.g. 55/45, 65/35 or 80/20). Detailed analysis on waste composition is needed.

CONTRIBUTING PROCESSES

It can additionally be concluded that cutting accounts for around 70% of the overall waste. Warehousing and Assembly account each for 15%. The daily production volume of finished RMGs can be estimated to be 105 -110 tonnes per day. The total number of produced items is assumed to be over 600.000 pieces per day.





To address this potential for waste reduction and revalorisation, the study systematically looked for circularity options in three areas at the factory and in another three areas at the cluster level. In total, 12 circularity options were identified (see figure below). The selection of the feasible options depends on several factors such as the enabling policy framework, availability and possibility of accessing financial resources, skills sets and the state of technology providers.

AT FACTORY LEVEL

1. Firstly, for **reducing manufacturing waste,** a more material-efficient cutting device that improves waste generation on a medium level is suggested as a technical solution. However, this would also require financial resources and technical capacities.

2. Secondly, to implement the **collection and separation for recycling**, collection and sorting would be an important measure to apply which could be effective in recovering the materials and also feasible to a medium level, considering that sorting would be handled manually.

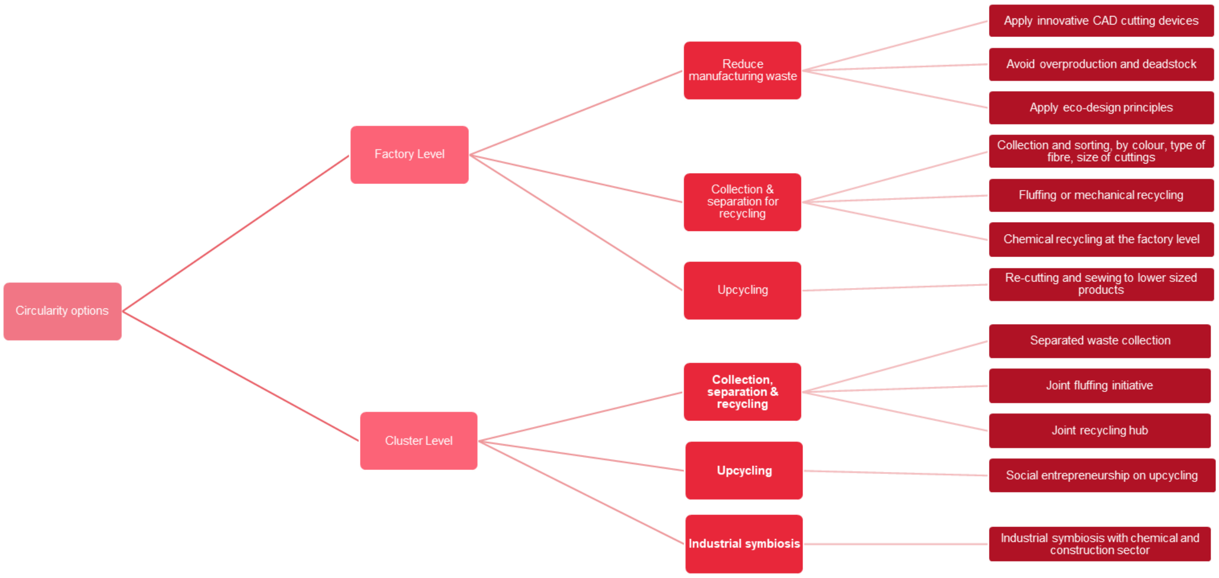
3. Finally, implementing **upcycling** for instance by re-cutting and sewing unusable fabric pieces into other products would be quite feasible, as it only requires hiring extra staff for this task. This process may not be particularly time-efficient but it can bring new business opportunities.

AT CLUSTER LEVEL

1. For implementing **collection, separation, and recycling**, waste collection would first need to be established. One potentially economically viable solution might be the joint operation of a fluffing process treating the sorted fabric waste all or at least a number of several textile companies in HIE. Another option might be set up of a joint recycling hub where the waste is collected from all factories and sorted for a fiber-to-fiber recycling solution.

2. Secondly, **upcycling** could also be implemented at the cluster level, by fostering social entrepreneurship for upcycling within the cluster.

3. Finally, for creating an **industrial symbiosis** it is necessary for the RMG factories to identify and approach one or several adequate sectors such as construction industry, with whom they could establish a regular material exchange.



NEXT STEPS

In the next stages of the project, circularity options will be further assessed for feasibility and built into business cases to be discussed with stakeholders. In addition, trainings for the industry and a supporting policy framework discussion will be carried out.

1 About this Study

1.1 Background

In Jordan, the production of textile and garments in industrial zones results in considerable amounts of solid textile waste that are presently disposed of in municipal landfills and specially waste from the ready-made garment (RMG) sector is of increasing concern. As commonly practiced, garments that do not meet the customers' quality standards as well as excess garment products that were not accepted or sold are thrown away. This textile waste is been treated as a cost factor harming Jordan's fragile ecosystem. However, textile waste also does involve numerous opportunities and could be recognised as a valuable resource on regional and international level on a long term.

The primary purpose of this study is to identify opportunities to minimise textile and garment waste, including recycling, upcycling and reuse measures in Al-Hassan Industrial Estate (HIE) and selected factories within the Estate. It therefore verified the outcomes of previous studies, which already explored steps towards circularity in the Jordanian RMG sector and complemented it with new data from 2022 from HIE on the updated volumes of production and waste. Furthermore, this study also aims to develop a list of circularity approaches at the factory and cluster level firstly for prevention of waste generation, secondly to treat waste resources more efficiently and thirdly for revalorisation of the waste.

This study is part of a wider intervention by the "Green Action in Enterprises" (GAIN) project and the "Promotion of Multi-Stakeholder Projects for Sustainable Textile Supply Chains" (MAP) project, both of which have been commissioned by the German Federal Ministry for Economic Cooperation (BMZ) and are being implemented by the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) *GmbH*. In close cooperation with the Ministry of Environment and the Ministry of Indutsry, Trade and Supply stakeholders are supported in the implementation of circularlity approaches in the Jordanian RMG sector.

1.2 Methodology

For the development of this study and verifying the previously available information, nine RMG semi-structured interviews were conducted as part of an administered survey to collect quantitative and qualitative data regarding the status quo of waste management in the textile industry cluster within HIE and a material flow analysis (MFA) of the participating HIE manufacturers was conducted. The survey included data from Classic Fashion, the biggest RMG manufacturer in the Middle East and North Africa (MENA) region. The Material Flow Analysis (MFA) allowed a comprehensive understanding of the amounts, types, hot-spots of waste generation and existing disposal channels for that generated waste, this created the basis to develop circularity options.

1.2.1 Qualitative data

The semi-structured interviews aimed to collect qualitative data regarding:

a) **Manufacturing processes:** To build an understanding of the RMG industry within HIE and their manufacturing processes, the value chains of different manufacturers were compared in order to develop a representative process diagram as a foundation for the material flow analysis.

b) **Sources of textile waste**: Information was received from the interviewees about where in the processes, significant amounts of textile waste are generated, so that the most effective interventions across the processes to reduce waste at source could be identified.
c) **Types of waste:** Information was collected from the interviewees on the types of the waste generated, in terms of fabric type within textile waste. Quantitative information was collected regarding other types of waste generated including packaging and organic waste.
d) **Current waste management**: It was assessed whether survey participants have already been implementing waste minimization measures within their manufacturing process. This included resource efficiency practices in those processes and quality management measures.
e) **Interest in circular economy initiatives**: During the interviews, the interest of interviewees in implementing circularity options within their manufacturing process was gauged. Potential partners that would be interested and committed to improving the environmental impact of their factories were identified.

1.2.2 Quantitative data

The survey aimed to collect quantitative data to address the following:

a) **Production volumes**: Each factory participating in the survey was asked to provide data regarding their daily production volumes, so that a clearer idea is built regarding their current production efficiency, as well as the share of each facility in the overall production coming out from HIE.
b) **Amounts of waste per waste type**: Waste volumes for textile, packaging and organic waste were acquired from each surveyed factory.

1.2.3 Survey participants

The conducted interviews included the following stakeholders' groups (see Appendix A for list of interviewees):

1. **RMG factories in HIE,** including nine out of 26 active textile manufacturers at the estate, including the biggest manufacturer in the estate (Classic Fashion).
2. **Cluster management,** including the HIE park manager
3. **Customs department,** interviewing the director of the HIE customes deparment office
4. **Waste contractor and landfill management** commissioned to collect waste from textile companies within the estate.

Appendix B shows the survey questions conducted with each of the stakeholders' groups.

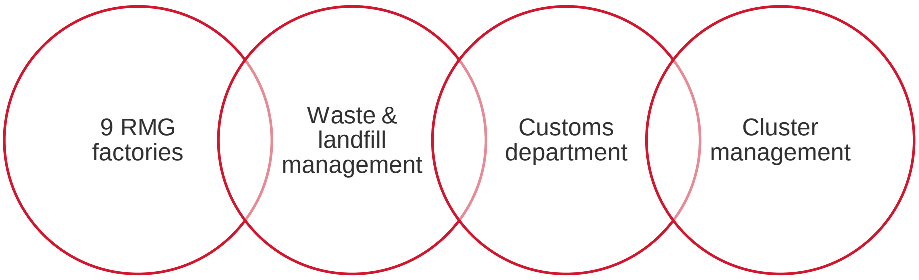


Figure 1: Overview of Survey Participants

2 Current Practices in HIE

2.1 Overview on HIE

The HIE is located in the Irbid Governorate, 72 km north of the capital Amman, Jordan. It was established in 1991 and in 1998 it was designated as the first Qualifying Industrial Zone (QIZ) in the world. HIE accommodates more than 154 factories (of which around 26 factories are garment manufacturer) with a total invested capital of more than JOD 489.5 million. As the largest QIZ in Jordan the HIE is creating more than 36,000 job opportunities.

The HIE hosts several manufacturing sectors including but not limited to the RMG sector, food and beverages, pharmaceuticals, chemicals industry, and plastic manufacturing. The factories are distributed across the area of the estate; there is no sectoral cluster distribution.

Figure 2 Maps of Al-Hassan Industrial State

2.1.1 Manufacturing Sectors

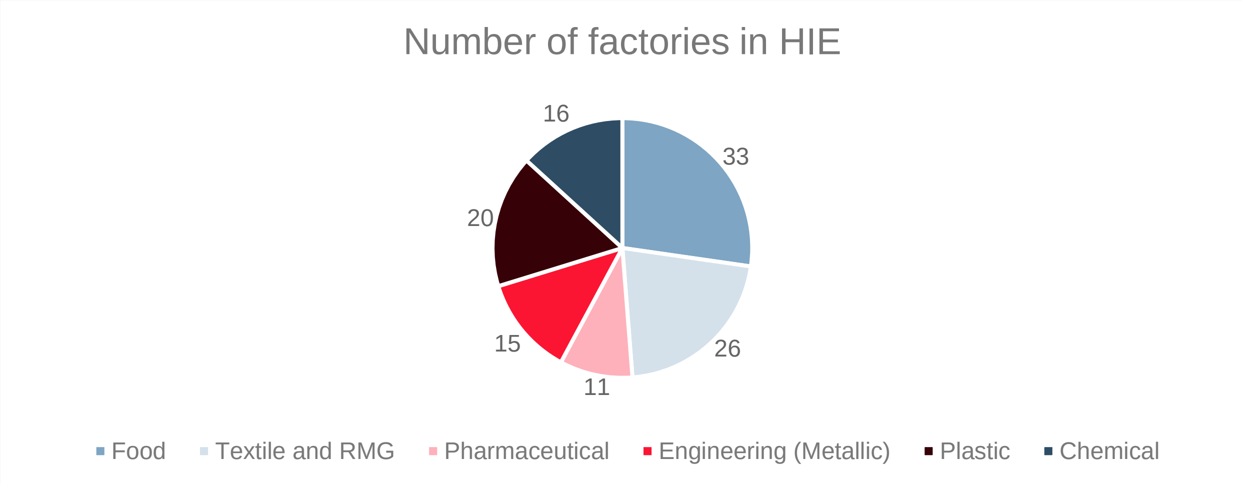
There are 108 more factories operating in HIE as illustrated below:

Table 1: Overview of industries present in the HIE[1]

#	Industry	# of Factories
1	Food	33
2	Textile and RMG	26
3	Pharmaceutical	11
4	Engineering (Metallic)	15
5	Plastic	20
6	Chemical	16

[1] Jordan Industrial Estates Company 2022.

6	Furniture and Kitchen	2
7	Printing and Packaging Paper	4
8	Leather	5
9	Construction	2



2.1.2 RMG Factories

The local RMG secotr at HIE is one of the largest in the region with the firm "Classic Fashion" factory being the largest in West Asia and North Africa (QANA) region. Classic Fashion alone produces and exports 75% of the total production of the cluster. The cluster produced an estimate of 35,000 tonnes of RMG in 2021.

There are 26 operating textile factories in HIE, listed below:

Table 2: Overview of RMG factories in the HIE, their volumes and employees[2]

#	Name of The Factory	Number of employees	Production volume (RMG pieces/day)	Interviewed
1	Al azya al taqledeyeh/ Classic Fashion	26000	500.000	X
2	Shareket Mojezet al asr / Century Miracle	2671	NA	
3	Al zafayer for clothes	900	10.000	X
4	Al maserah Company for textile	800	5.500	X
5	Darb Al tabanah for clothes	566	12.000	X
6	Abu Ghazi and Khair al deen	270	NA	
7	Sanaa for clothes	450	3.500	X
8	Al naweyah for clothes making	223	NA	
9	Al anaqa al duwaleyeh for clothes	270	5.500	X
10	The Engineer company for clothes	40	1.500	X
11	Haifa Factory	330	2.000	X

[2] Data from Park Manager and interviews with factories, 2022

12	Al khat al mustaqeem for clothes	113	NA	
13	Bawabet al salam for clothes	42	NA	
14	Mushi koheen (musa factory)	42	NA	
15	Sesban for clothes making	41	NA	
16	Kareem for clothes making	24	NA	
17	Tarkeet for textile	20	NA	
18	Funuun al kutun for clothes	15	NA	
19	Kadi for clothes making	15	NA	
20	Banda shweikh for Blankets	11	NA	
21	Al meyaar For jeans and clothes	10	NA	
22	Aziza abdulqader (Al jedaa for clothes	10	NA	
23	Abwab Al khair for clothes	9	NA	
24	Al bashayer for making clothes	7	NA	
25	Noor l madeneh lel tejara	6	NA	
26	Seen wa taa' lel kuton	3	NA	

2.2 Waste management

2.2.1 Legal waste management framework in Jordan

Solid waste management legislation falls under the mandate of the Ministry of Environment (MoEnv) in Jordan, with enforcement support from the Ministry of Local Administration and Local Municipalities (MoLA). The Waste Management Framework Law No.16 of 2020[3] is the main legislation which regulates solid waste management in Jordan which was put into effect in 2021.

Article 7 of this law stipulates the following key principles guiding the waste management:

Table 3: Principles of the Jordan Waste Management Framework Law of 2020

Principle	Definition
Prevention Principle	Adopt effective and appropriate measures aimed at avoiding generating waste or limiting the amount of waste and its harm to the minimal possible level, in order to reduce risks to the public health and environment, and to reduce environmental degradation.
Precautionary Principle	To take preventive measures to avoid any threat or risk to the environment.
Extended Responsibility Principle	Holding generators and importers of materials and goods with the financial responsibility for the environmental impacts of their products or the residuals of their products from Treatment or Final Disposal and the primary production activities in selecting materials and in product design, when negative impacts arise and the development of an

[3] Ministry of Environment. 2020.

	approved national mechanism for its Treatment according to instructions issued for this purpose.
The Polluter Pays Principle	The generator or holder of the waste incurs the costs of prevention, recovery and disposal of waste, including subsequent follow-up and monitoring, and the generator's financial responsibility for preventive and rehabilitative measures when it causes or may cause harm to the environment.
Proximity Principle	Treating waste or disposing it at the nearest site or establishment taking into consideration economic and environmental efficiency.

The law also provides for the establishment of the Highest Steering Committee for Waste Management, which among other duties is tasked with adopting the policies, strategies and executive programs for waste management in the Kingdom.

According to this law, the MoLA in Jordan is held responsible for waste management, supervision and monitoring in the municipalities, joint services councils (JSC), slaughterhouses, as well as vegetables and fruits markets that fall within its competence with regards to the waste collection, transport, sorting, recycling, storage, treatment, investing in waste and final disposal. And it may seek assistance of the private sector.

Industrial waste is usually transported via private companies to the landfills and is then managed by local councils. **Article 16 of the solid waste management framework law mandates that any establishment which generates on annual basis more than one thousand tons of non-hazardous waste or any amount of hazardous waste with the exception of construction and demolition waste, shall set a plan to manage its waste and submit this plan to the MoEnv**. This plan is updated every five years and should include:

1. Documenting the generated waste to include the source, quantities, types, and components of the waste.
2. Precautionary measures and procedures to prevent or reduce waste generation.
3. Demonstrate all operations of waste separation, especially hazardous waste from other reusable waste.
4. Description of the waste storage mechanism and demonstrating it on the site.
5. The methods used to treat and dispose of waste.
6. Determining the routes of waste transport vehicles.

The production of textiles and garments in industrial zones in Jordan result in considerable amounts of solid textile waste that are presently disposed of on municipal landfill sites. In 2021 the resulting fabric waste from HIE amounted to almost 11,000 tonnes (as per records received from Al-Ekeider Landfill Management), wheras Classic Fashion is the main waste contributor within the textile sector at HIE. For HIE, containers are provided to collect and transport fabric and solid waste to the Al-Ekeider Landfill.

2.2.2 Waste collection

There are designated waste collection points to which textile manufacturers send their waste for collection by the waste contractor. The collected waste is then sent to the Al-Ekeider landfill. The map below shows the layout of the landfill.

Figure 3: Map of Al-Ekeider Landfill

Figure 4: Distance and Main Route between HIE and Al-Ekeider Landfill

2.2.3 Al-Ekeider Landfill

Al-Ekeider landfill is the second largest landfill in the country and the closest landfill in reach of the HIE. It is located close to the Syrian border near the Valley that runs from Jordan to

Syria. The site is currently owned and managed by the Joint Services Council (JSC) of Irbid Governorate which comprises several municipal councils.

In the initial five years of its operation, the landfill received solid waste generated from the Irbid Governorate. However, from 1986, the site started receiving waste also from other governorates. As of today, it is serving a total of 30 municipalities in four different governorates, with a total population of around 1,000,000 [4].

Al-Ekeider landfill has become the focus of several international donor organisations and cooperation efforts. The Canadian embassy, UNDP, EU, and the German government, among others, provided technical and financial support to improve solid waste management in this location, such as the EU commissioned “Integrated Solid Waste Management” project to protect water table and surrounding environment, upgrade the landfill’s environmental performance, and avoid the danger of cross-border pollution towards Syria while also limiting the emssions generated from the landfill.

Besides municipal solid waste including domestic and industrial non hazardous solid waste from 31 surrounding locations, **Al-Ekeider receives mixed waste from HIE including textile waste**. As of October 2021, the Ministry of Local Administration announced that Al-Ekeider Landfill will no longer accept textile waste from HIE, as the land used for textile waste disposal will be rehabilitated for other uses. So far, the HIE and Al-Ekeider landfill received in October 2021 an official letter from MoLA stating that textile waste has to be diverted to another location. This was highlighted by Al-Ekeider landfill management during the interview we conducted with them, and they indicated that this decision was later overruled. **The Landfill was continuing to receive textile and other waste from the textile cluster at HIE during the writing of this report.**

2.2.4 Textile waste classification

The Waste Management Framework Law No. 16 of 2020 classifies waste into two types, namely hazardous and non-hazardous waste. The waste generated from the textile industry at HIE is classified as non-hazardous waste.

Textile factories at HIE separate their waste into organic waste, and production waste. Production waste includes fabric waste, cardboard, and plastic packaging.

Fabric waste is almost entirely generated at the cutting phase of the process, while cardboard and packaging waste is generated mostly when raw materials leave the inventory to enter production. Organic waste is mostly waste coming from employees’ canteens/dorms.

According to information received from Al-Ekeider landfill management, textile waste is sent to the landfill in containers designated only for fabric waste, while plastic and cardboard packaging, as well as organic waste is sent to Al-Ekeider separately in other containers. Classic Fashion indicated during our interview with them that the fabric waste sent to the landfill does not include finished RMG, as the finished products that do not fulfil the quality check are either shredded, then sold as fluff or modified, then sold as b-quality goods.

The diagram below demonstrates waste classification for the textile waste industry at HIE.

[4] European Environment Agency 2017.

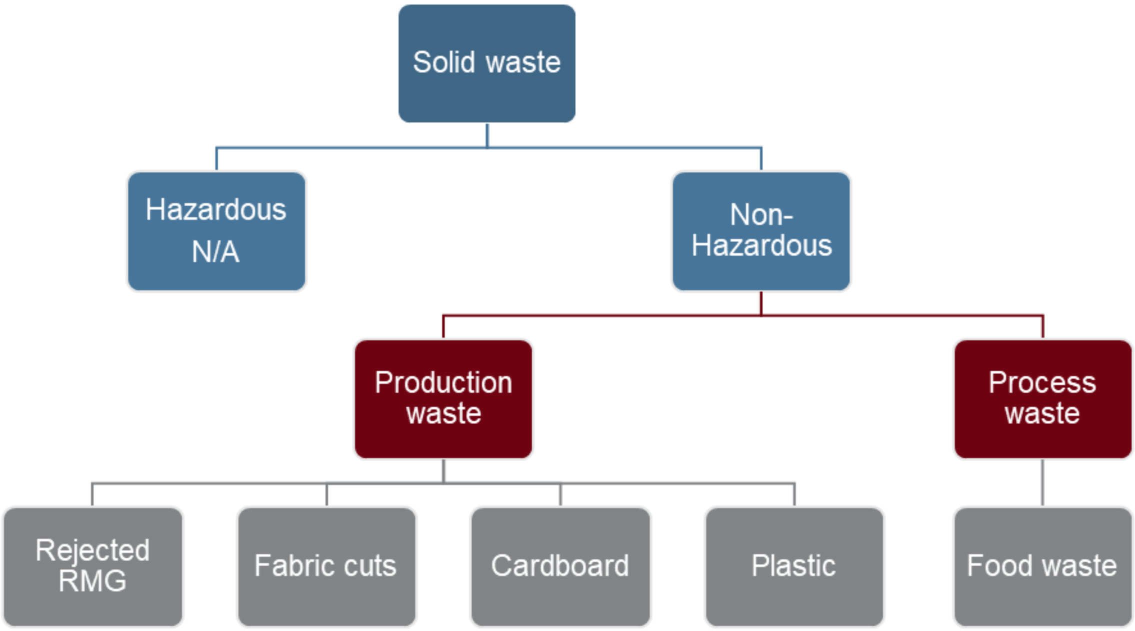


Figure 5: Waste Classification in HIE

Figure 6: Textile waste from fabric cutting at Galaxy Factory in HIE

Figure 7 Wooden Pallets at Galaxy Factory HIE

2.3 Existing waste minimisation and circular economy efforts in HIE

Existing waste minimization and circular economy engagements at HIE are minimal, driven mostly by cost reduction. Compliance represents a weak driver in terms of waste separation and disposal on landfills.

2.3.1 Waste reduction engagements

Waste reduction efforts within the HIE fall under one of two categories, cutting optimization and quality management:

Cutting optimization

All of the surveyed companies indicated that they implement programs to limit waste at source, specifically in the cutting phase, to improve production efficiency (yield from fabric raw material). Four out of the surveyed manufacturers at HIE implement automated cutting, which is optimized to reduce the amounts of cutting waste coming out when cutting patterns. Two of the surveyed factories do not implement this automated cutting technology, whereby the design patterns are either sent in by customers or are drawn manually. In the latter case, the textile waste as a percentage of the input raw material input is relatively high.

Eliminating Cutting Waste through Seamless knitting

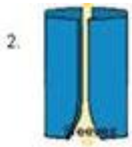
One factory at the HIE, namely Al Maseerah implements seamless knitting that leads to almost complete elimination of cutting waste (see case study box below). This method can only be applied in knitting factories for certain types of garments. The way the seamless garment is designed and how the final size is obtained is fundamentally different compared to garments produced on a traditional cut-make-trim route. Since no fabric cutting is required here, the designer of a seamless garment has to calculate the measurements back from a finished garment piece to arrive at the specifications for knitting one of the pieces, because an original undyed garment can has dimensions 10-35% larger than the finished garment. The customer has to offer a detailed specification to minimize any finishing tasks. Circular knitting machines used for making seamless garments are based on programmed computer commands.

Case study: Al Maseerah Knitting Process [5]

3 Steps knitting method:

1) Body Knitting

2) Sleeve Knitting



3) Sewing

With industrial progress, the advancements in garment manufacturing have evolved from cut & sew to complete garment knitting, which produces one entire garment without sewing or linking process.

Seamless Knitting Technology is a method developed in Italy in 1984 to produce better fitting garments. The seamless concept spread all over the world with a surprising quickness because it allows to get to the finished garment in a few minutes starting from the yarn and without passing through cutting and sewing operations, it offers savings in terms of production times and cost, and it minimizes yarn consumption. S

The raw material for this technology is yarn, yarn (usually a combination of cotton and spandex) is spun to knit the whole pattern of one style into one sheet. A seamless knitted sheet for a shirt will contain one piece for the body, two sleeves, one collar, and two cuffs. This technology allows the production of better fitting, more comfortable clothing, and that's why it's employed in sportswear more than anything else.

Another advantage of this technology is the drastic reduction of cutting waste. The specialised circular knitting machine can make the entire product in few minutes and save up to 40% of the original fabric that may go as waste or cut-loss in the conventional method.

The style pattern in seamless technology is digitally developed and fed to the knitting machines. The figures on the left show the components of a seamless shirt pattern

The figure below shows the steps in seamless production vs traditional production.

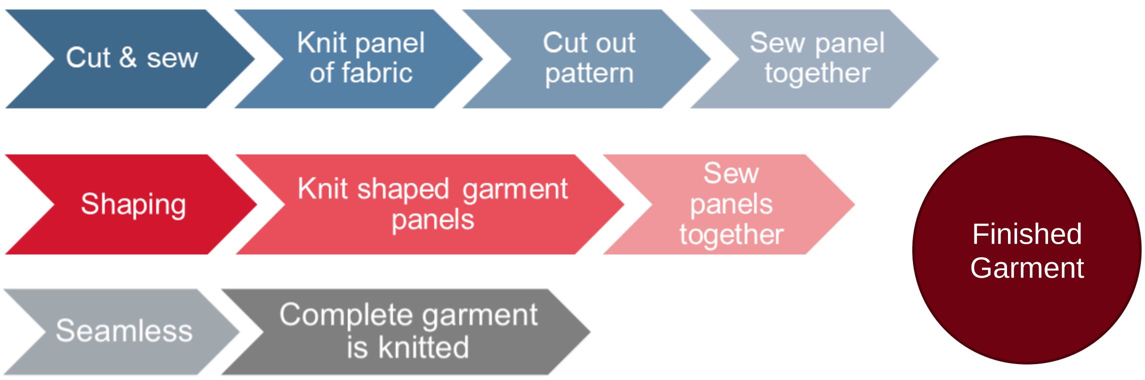


Figure 8: Traditional knitwear production process (1), (2) and seamless production (3)

Quality Management

When surveyed about how quality reject is handled, most manufactures engaged in the survey indicated that pieces which do not pass the quality check are mostly returned to the process for modification or sold as second grade products where customer agreements allow for that.

[5] Interview with Al Maseerah factory 2022

Other engagement

In relation to other production waste, including plastic and cardboard packaging as well as wooden pallets, few manufacturers indicated that they sell the waste to local recyclers outside of HIE, or in the case of wood pallets they keep them for reuse/ repurposing. Secondary raw materials or waste is not yet actively exchanged between factories of HIE.

3 Material Flow Analysis

3.1 Methodology

3.1.1 Framework

A Material Flow Analysis (MFA) was conducted as part of the assignment to identify the origins, amounts, and disposal practices of different waste streams generated from RMG factories at HIE. To collect the information which is necessary in order to develop a MFA, the project team has conducted interviews with the main stakeholders present in the cluster (see Annex A).

Given the spatial boundaries of HIE, the MFA is concentrated on material flows in the area within HIE. The data collected are focused on the year 2021.

The MFA covers the fabric flow from packaged fabric entering first the cluster to RMG and mixed waste containers leaving HIE. The data collection has identified fabric, plastic and paper as the main waste material flows of the assessed system. Other flows such as organic and wood waste are neglected in this assessment.

3.1.2 Data collection

The primary data collection consisted of a survey with nine factories as well as four key stakeholders such as the customs office representative at HIE, landfill manager, waste collector and park manager. As can be taken from Table 2, the following factories were interviewed:

- Al Azya Al Taqledeyeh ("*Classic Fashion*")
- Century Miracle
- Al Zafayer
- Al Maseerah
- Darb Al Tabanah
- Sanaa
- Al Anaqa Al Duwaleyeh
- The Engineer Company
- Haifa

Primary data such as collected interview responses was complemented by secondary research data such as a database exract from the customs department. These data allowed the project team to collect information regarding the type of waste generated, amounts, and disposal practices.

Monitored data from the customs departments official database was additionally screened for verifying survey results as well as to address some of the data gaps. Generally, data representativeness might be limited by the fact that the year 2021 was affected by the global Covid-19 pandemic, which may have affected the factories productivity in comparison to years before or after the pandemic,

3.2 Value chain

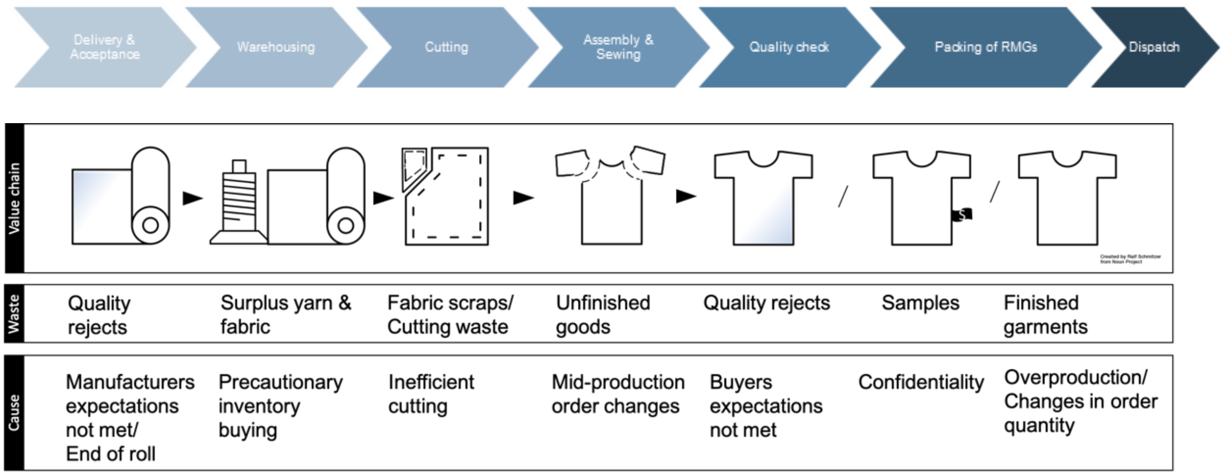


Figure 9: Value chain of RMG manufacturing in HIE

It was confirmed by most of the interviewed factories that the value chain processes pictured in Figure 1 are in line with their production line with two exceptions. The Sanaa factory usually receives pre-cut pieces to assemble, accessorize and package. In contrast to the other factories, processing fabric rolls themselves accounts for less than 10% of their production. The other exception presents the only interviewed knitwear factory Al Maseerah, which does not operate any fabric cutting process as their production follows the logic described in Case study 1.

3.3 Input analysis

For identifying input material flows, data was obtained from the customs office. This data was was based on Harmonized System (HS) codes from the custom department regarding the fabric (and fabrics related) materials that entered the cluster. HS codes are commonly used throughout the export process for goods and represent a standardized numerical method of classifying traded products[6].The ones which are relevant for the study are the HS codes from 50 to 63 (see Annex C).

[6] https://www.trade.gov/harmonized-system-hs-codes

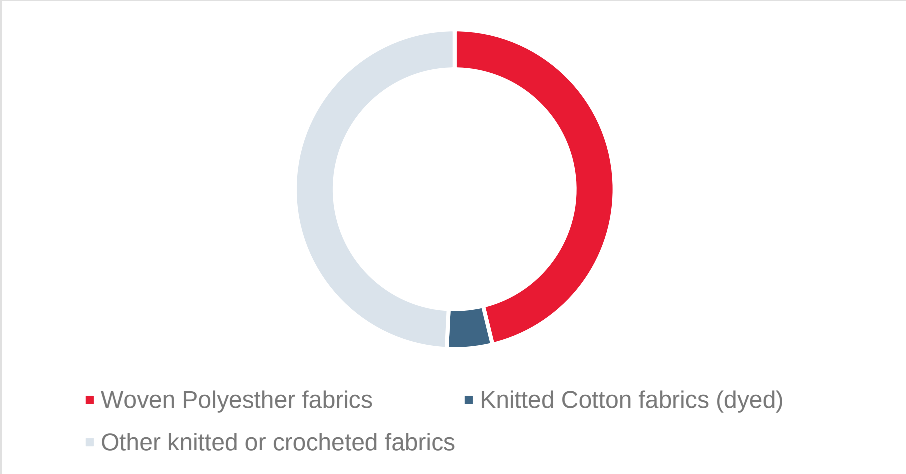


Figure 10: Input Materials according to their HS Code categories

The obtained import data provided by the customs department were not available on an annual basis, but as a sum of the year 2020 and 2021 (a total of 84.700 tonnes of imported fabric in both years). According to the interviewed stakeholders, the two years showcased differences in material that entered the HIE. . A 14% increase in textile waste from 2020 to 2021 was officially recorded by the landfill manager. Based on this, it was assumed that there is a linear connection between increased increased textile input (fabric) and textile output (textile waste) . According to these extrapolations 141 tonnes of fabric (± 10%) have approximately entered the cluster daily in 2021[7]. This amount includes packaging (mainly paper and plastics) that will later become packaging waste.

Among the interviewed factories, six out of eight stated that they are using fabrics made from polyester and other synthetic fibres, whereas four of them use both polyester and cotton and two only use synthetic fibres such as spandex, rayon and nylon. Five companies use blends between cotton and polyester or other synthetic materials with polyester. The stated material blends with polyester/cotton are 55/45, 65/35 or 80/20. Only one womenswear factory uses mainly cotton.

3.4 Output analysis

This analysis aims in studying the flows of materials leaving the cluster after they have been processed by the fabric companies.

Two main types of outputs relevant for this MFA study are:

- **Mixed Waste** in the form of fabric, plastic, and paper.
- **Finished RMG.**

3.4.1 Waste volume

For defining the volume of waste generated, the project team interviewed the main stakeholders active in the waste collection and disposal of the residues generated by the

[7] The 10% uncertainty is based on a deviation of actual waste numbers from the estimation made by the customs department, which was based on a production effeciency assumption of 78%.

companies in HIE (see Annex B for the survey questions). The results of these interviews are summarised below.

Landfill manager

According to the database by the Al Ekeider landfill manager, 33,6 tonnes of waste are created and disposed daily in the cluster by RMG factories. The biggest factory, Classic Fashion (CF) accounts for 16,8 tonnes of the waste disposed per day. It must be noted that CF has one main production site and several smaller production factories present in HIE. The share of CFs biggest factory makes up 50% of the total waste from RMG factory.

The smaller factories of CF also get their waste collected, before being transported to Al Ekeider landfill, however, the collection point is shared with other (non-CF) RMG factories and therefore the waste amounts are neither distinguishable by factory nor recorded seperaratelу.

Data from waste collector

Al Nabali, the waste collection company in HIE, estimates an amount of 30-40 tonnes of mixed waste (fabric plus packaging) generated in the cluster on a daily basis. Since no data records have been made available by the waste collector, it can be assumed that estimates are based on the number of truck loads the company collects daily. The waste collector confirmed that the majority of waste collected are fabric waste, and that CF represents the biggest waste generator from the 26 companies.

Surveys with factories

The project team interviewed nine companies out of the 26 operating in HIE as stated above. According to the employees' number, the nine interviewed companies represent a cumulative 89,3% of employees share.

Interviews of various stakeholders confirm that CF make up a majority of the waste from all RMG factories. The remaining eight interviewed factories besides CF, are among the 11 biggest factories in the cluster and make up 10,2% of total employees in the RMG sector and account for 3,74 tonnes of mixed waste per day. Twelve of the overall 26 factories with less than 40 employees were not targeted in the survey and can be neglected in this analysis as they only account for 0,4% of the employee share of the cluster.

3.4.2 Waste composition

The nine interviewed companies provided information regarding generation volumes for their different types of waste. It must be noted that various factories stated the amount of waste measured in containers rather than providing weigh records. This measuring unit had to be converted into tonnes based on average waste densities. Therefore, assumptions had been made to convert the different measuring units and allow a uniform calculation.

Based on the survey it was found that **the generated waste from RMG factories consists of 90.2% of fabric, while plastic and paper make up for around 5% each**.

Table 4: Shares of waste types contributing to waste from RMG factories in HIE (2021)

Type of waste generated	Share (%)	Tonnes of waste per day
Fabric	90.2%	30,32
Plastic	5,0%	1,67
Paper	4,8%	1,62

In line with the survey responses, it can be assumed that the fabric waste consists mostly of 100% cotton, 100% polyester or blends between polyester/cotton or polyester/other synthetics in different ratios (e.g. 55/45, 65/35 or 80/20).

3.4.3 Waste sources/contributing processes

According to the survey, material delivery, quality check, packing, and dispatch generates minimum to no waste at all. For instance, it was explained by two of the interviewed factories that defective rolls of fabrics from the delivery phase are either fixed, by removing the defective part or completely rejected and sent back to clients and therefore only contribute to their own waste in a very limited manner. Therefore, the waste composition analysis focuses on the waste generated during warehousing, cutting, and assembling.

Based on survey results it can be concluded that cutting accounts for around 70% of the overall waste. Warehousing and Assembly account each for 15% as it is shown in Table 5.

Table 5 Shares of processes contributing to waste from RMG factories in HIE (2021)

Total waste generated in the processes	Share (%)	Tonnes of waste per day
Warehousing	14,9%	5,02
Cutting	70,1%	23,54
Assembling	15,0%	5,04

The table below shows the breakdown between the waste share and material composition in each process. Overall, fabric represents the bulk of waste produced. Among these processes, most of the fabric waste is generated during cutting (23,17 tonnes/day equal to the 98,4% of the cutting waste), while plastic and paper wastes are generated the most during warehousing (1.29 tonnes/day each).

Table 6: Breakdown of different waste amounts generated per process (2021)

Process	Materials	Share (%)	Tonnes of waste per day (HIE)
Warehousing	Fabric	48,8%	2,45
	Plastic	25,6%	1,29
	Paper	25,6%	1,29
	TOTAL	**100%**	**5,02**
Cutting	Fabric	98,4%	23,17
	Plastic	0,9%	0,20
	Paper	0,7%	0,17
	TOTAL	**100%**	**23,54**
Assembly & sewing	Fabric	92,9%	4,68
	Plastic	3,8%	0,19
	Paper	3,4%	0,17
	TOTAL	**100%**	**5,04**
Overall Total			**33,6**

In the following, the manufacturing processes are described step by step to emphasize again which processes contribute in what way to the generation of waste. In addition, the waste contribution amount is stated for each of the value chain steps. As can be taken from this description, some of the processes did not generate significant amounts of waste and their contributions has been perceived as negligible according to the interviewees of the survey.

Table 7: Description of value chain processes in RMG manufacturing and their contribution to waste generation

Delivery & Acceptance

Delivery & Acceptance

During this phase, raw material is delivered to the factory and inspected by a quality manager who may accept or reject the delivery. However, according to the survey, six of the interviewed factories agree that it is extremely rare that a whole fabric role is wasted, since either the roll is sent back to the supplier in case of defects, or the defective part of the fabric roll is cut off. Classic Fashion states that 10% of the deliveries are usually randomly sampled, quality checked and if the fabrics do not meet their expectations, the whole delivery is returned to the supplier. Therefore, factories consider the amount of waste generated in this phase negligible.

- ➔ The waste generated from RMG factories during delivery and acceptance is **negligible.**

Warehousing

The qualitative data from the interviewed factories shows that during warehousing, waste mainly occurs as packaging waste. This process follows an initial quality check at the delivery. The delivered fabric rolls are usually unpacked from transporting packaging material before they are stored in the warehouse. The interviewees indicate waste from poly wraps and cardboard boxes as well as wooden pallets, although the later are reused more often. Nevertheless, the fabric is still often kept in plastic for protection in order to avoid pest contamination.

➔ As can be taken from Table 6, around **5 tonnes of waste per day** is generated from RMG factories during warehousing.

Cutting

In this phase, fabric rolls are taken out of the warehouse and brought to the cutting machine where the fabric is unrolled, usually stacked with many layers, then the stencils are calculated and applied to the top of the stack before the different pieces of the final product are cut out by a manual or automatic cutting device. Besides the removal of protection packaging material after warehousing, a lot of additional single-use plastic and paper occurs when the fabric is layered. In order to ensure a clean cutting result, plastic and paper layers are usually inserted between fabric layers as well as on top of the layers. When the fabric is finally cut, the paper and plastic layers from both the usable pieces of fabric and from the cut-off fabric goes to waste. However, by far the highest waste contribution in this phase is the fabric cut-offs, which consist of remnants that are usually too small to fit another stencil of a garment piece on it. As a result, the fabric ends up in waste collection.

➔ As can be taken from Table 6, around **23,5 tonnes of waste per day** is generated from RMG factories during cutting.

Assembly

During assembly the cut fabric pieces are delivered to the sewers, who then assemble multiple pieces together, combine them by sewing and finally trim any access fabric or yarn. The waste from this phase mostly consists of yarn and fabric pieces, while some plastic and paper is used during assembly as protection material while fabric pieces half-finished goods are stored. The biggest factory at HIE stated in the interview that waste from the assembly phase is usually sent to the fluffing machine. There it is turned to fluff (1 - 1.2 tonnes per day), while the rest is sent to landfill, which costs around 20,000 JOD per month.

➔ As can be taken from Table 6, around **5 tonnes of waste per day** is generated from RMG factories during assembly.

Final quality check and packaging of RMGs

In this phase the RMGs go through a final quality check, before being packaged and prepared for dispatch. The quantitative data from the survey revealed, that factories generate almost no waste during these final phases. However, it must be considered that the factories strongly contribute to packaging waste generation indirectly. The amount of packaging material used in this phase by the factories defines the amount of waste generated at their buyers' location.

- ➔ The waste generated from RMG factories during the final quality check and packaging of RMGs is **negligible**, as final RMGs are either shredded and sold as fluff or repaired and sold as b-quality goods
- ➔ However **indirect contribution to waste** for their packaging process has to be considered.

3.4.4 Production (RMG)

The production amount was calculated as a difference between fabric input and waste output. It can be estimated to 105 -110 tonnes per day. The total number of produced items is assumed to be over 600.000 pieces per day.

3.5 Findings

On a cluster level, 76.2% of input material is transformed into RMG, while 23.8% counts as fabric, plastic, and paper waste **for a total waste generation of 33,6 tonnes/day.** This means, around one fourth of the input material such as packaged fabric roles becomes waste after the manufacturing process is finalized. According to other studies, the amount of waste during textiles and apparel manufacturing can range from ~12% to 15%, but can be as high as 25–30%.

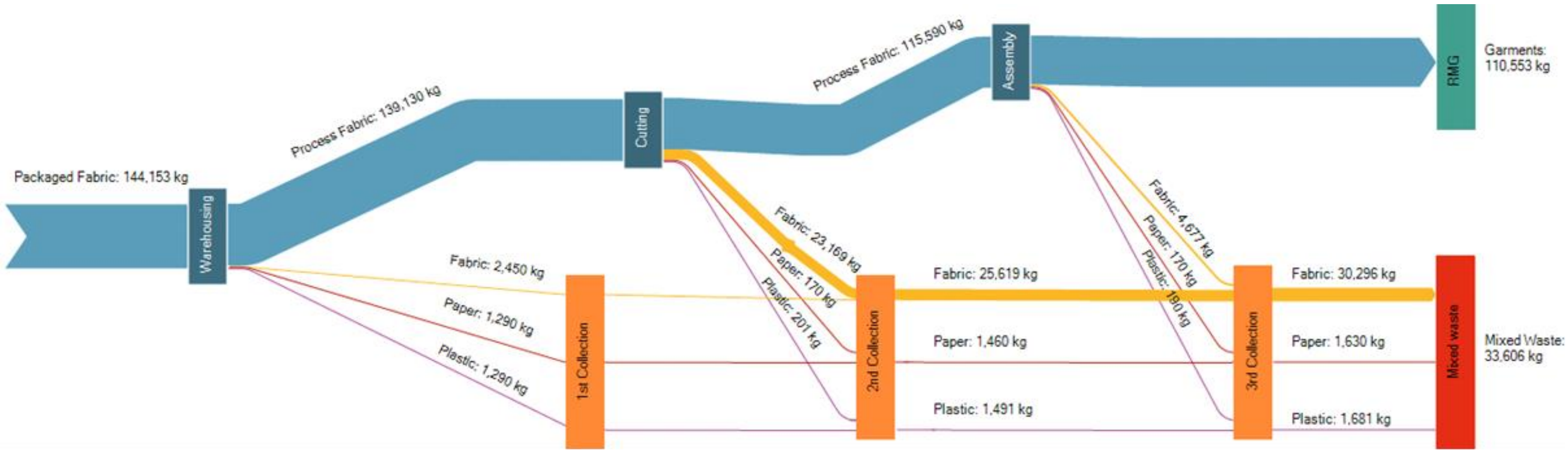
To that end, our findings indicate at:

- Of the waste amount from RMG factories at HIE, **90% consists of fabric waste** while packaging only accounts for 10% of the waste generated. As can be taken from the Sankey diagram (Figure 11), the three material streams remain separable throughout the whole system. Nevertheless, they are mixed after each process that contributes to waste accumulation. This results in a final output stream that consist of a mixture of three material streams.
- There is **an opportunity either to avoid fabric** waste with cleaner production measures as the amount is currently above the industry average.
- Between all processes, **the cutting process accounts for 70% of the total waste generation (23,5 tonnes of waste per day)**. Most fabric waste appeared in the process of cutting, while plastic and paper mostly accumulated after the fabric rolls were accepted and packaging materials were removed. 78% of plastic and paper waste occurs during the warehouse process. Studies confirm, that the cutting process is

among the two most wasteful processes in the textile value chain. Only yarning which has not been considered in this study, generates even more material loss among the entire value chain.

- **By avoiding mixing of the waste** and keeping the material streams separate, **the foundation for further circularity options can be established**.

In the next chapter, it will be discussed how the waste that occurs along the production line could be avoidable and how the waste could be valorised into other uses through upcycling, downcycling and recycling.



1. *The figures are daily amounts, and refer to the year 2021.*
2. *The collection point in reality are mixed waste containers. The distinction between waste flows has been done only for illustrative purposes.*
3. *No distinctions between RMG products has been conducted.*
4. *Other types of waste (e.g. food from canteens, packaging wood, etc.) are neglected in this assessment.*
5. *It considered that all imported goods in 2021 have been used in the same year, and not material from years before have been processed in 2021.*

- Process Fabric
- Fabric waste
- Paper waste
- Plastic waste
- Finished RMGs
- Mixed Waste
- Collection Points
- Manufacturing Processes

Figure 11: Sankey diagram based on MFA illustrating material flows along the RMG manufacturing processes in HIE

4 Circularity Options Scan

Effectively implemented circularity in the textile value chains entail upstream strategies where decisions focus on regeneration and conservation of materials, retaining material value at the highest level[8]. Designing for zero-waste manufacturing, designing for durability and modularity, repairing, and upgrading as well as shifting to more environmentally friendly or recycled fibres can be the steps towards closed-circle value creation in textile product chains.

Lower levels of circularity put focus on the downstream processes of value chains and good waste management practices. In this respect, reduction of waste in the factory is seen as the first option. The production processes in the factory are analysed for leakages and are optimised for waste prevention. If waste creation is unavoidable, valuable materials in the waste can be partially recovered for a second life. Recovery means collection, separation, recycling, and upcycling. Moreover, a design for disassembly, reassembly and recycling can play an enabling role for recovery (See Figure 12).

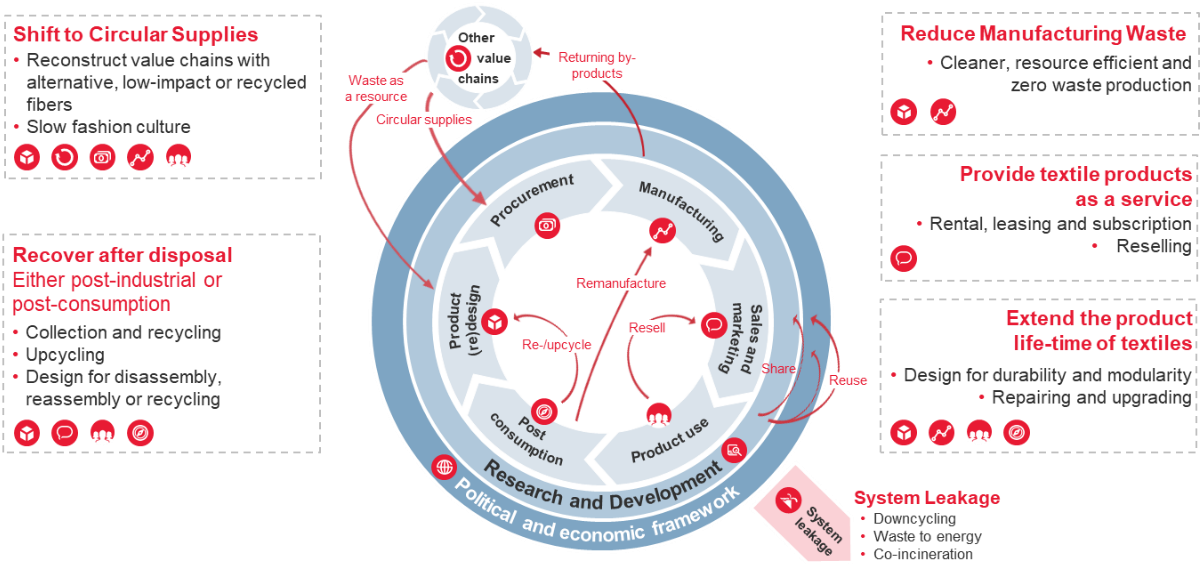


Figure 12: Framework for circular textiles (Source: adelphi own based on Accenture, 2015 and SCP/RAC, BCSD, 2020)

In fact, downcycling by waste to energy schemes, incineration plants and dumping in landfills are not circularity solutions as it indicates leakage of valuable materials from the system. If all options of circularity are considered infeasible, the materials would then reach their end of life being disposed into nature, often with negative environmental consequences.

In this study, only downstream processes and lower levels of circularity are considered in the biggest factories of HIE. This is because these types of companies have no direct influence on product specifications of up- and midstream manufacturing processes. The RMG companies are located at the end of the value chains and hence, they would be able to intervene at the lower levels of circularity.

[8] **Retention of resource value means the conservation of resources closest to their original state**. From the producers' perspective, the value of finished, marketed and sold products can be retained as long their functionality is maintained and they can be reused and given successional lives. Keeping a product's value high over a long period of time requires a shift at the managerial, organisational, political and mindset levels as well as high-level coordination within product value chains. Hence, the strategies at the higher end of the list would normally come at a higher cost and with extended responsibilities for traditional companies and businesses operating in a linear economy. (Mosangini and Tuncer, 2019)

This chapter explores waste minimisation options at the factory level in the first place, then waste upcycling and recycling measures for post-industrial waste at both factory and cluster level, as well as industrial symbiosis (material exchange) opportunities, using local and international common good practices.

Specifically, it explores waste prevention options within the biggest factories at HIE, along their production lines, and then assesses material recovery options that a factory can implement in the case that post-industrial waste can't be prevented. Secondly, options beyond a single factory level are assessed, particularly to explore whether recovery options can be collectively created among several companies including the option of linkage to other value chains through industrial symbiosis.

For each option, the theory behind it, the required conditions as well as enabling factors for for its implementation are discussed. Real case studies from the MENA region illustrate how the options are put into implementation. Following that, an inital assessment of each respective option is provided and then, it is concluded whether the respective option seems feasible or not, as well as which enabling factors still need to be checked or be in place for implementation. The initial conclusions drawn from this report will however be enhanced again at a later stage of the project.

4.1 Circularity options at factory level

Implementing circularity on the factory floor requires a fundamental paradigm shift and transformation of industrial operations in which waste is understood as a valuable resource. In fact, the concept of waste needs to be entirely eliminated by designing products for defined application scenarios, disassembly and recycling in either biological or technical cycles.

In a circular economy, actors collaborate along and beyond the value chain to optimize the eco-effectiveness of the entire ecosystem to create shared value (Braungart et al. 2006). Local and adapted production is given priority and down-cycling is avoided wherever possible in order to maintain the material value of products and components for as long as possible.

Full closed-loop recycling of post-consumer-waste requires specialised recycling technologies that follow processes like sorting, separation, shredding and discolouring. High volumes of **single-origin pre-consumer-waste** (i.e. clothes made from mono-fibres) require less complex technologies for a closed-loop recycling. Innovative recycling technologies already exist, which can deliver solutions for various recycling approaches.

Nevertheless, various challenges and barriers exist, which hamper the implementation of circularity. Some of them are displayed in Table 8.

Challenges	Barrier
Quality	Low-grade quality of collected textiles makes it difficult to keep high value of products as long as possible
Standardization	Lack of recorded data of the amount and composition of textile waste prevents the development of a standardized procedure for collecting and processing the waste
Information exchange	Limited information exchange between value chain processes due to high complexity of network

Market environment	Low market penetration of innovative start-ups and path dependencies for established businesses in competitive market environments
Externalisation of costs	Externalisation of costs leads to underdeveloped infrastructure for separate collection and recycling, textile exports and lack of funding
Policy gaps	Absence of extended producer responsibility (EPR), inconsistent policies, lack of global governance mechanism for textile supply chains and regulatory barriers

Table 8: Challenges and Barriers of implementing circularity at the factory level

4.1.1 Reduce manufacturing waste at factory level

The theory behind this circularity option

The main indicator for waste reduction is less waste generated per amount of transformed material. Specifically, for RMG manufacturing companies, hot-spots for material waste are the roll-ends and cutting of garment pieces as well as the detection of in-production and end-of production rejects during quality checks. The application of modern and innovative CAD cutting devices have the potential to reduce the amount of cutting waste. These technologies are in general standard of the art and need skilled operators to achieve optimal results. On the other side, optimising resource use by making full use of these up-to date technologies also depends on the ambition of the brands to implement eco-design principles in earlier value chain processes. For instance by following recyclability criteria at the design stage such as adjusting the fabric width to the product design.

Overproduction and deadstock can also lead to the creation of avoidable post-industrial waste, as they can be minimised by good communication and planning between the producer and the customer. Also, carefully planning while producing samples and prototypes can reduce the production waste. Additionally, correct estimation of fabric consumption can help reduce waste by minimizing orders of excess fabric quantities.

Case Study: Improved CAD Cutting in Jeans production

©Riccardo Scauri for Unsplash

A jeans company had some computer aided marker development which still relied on manual input. This setup led to a potential of unoptimized patron arrangement for cutting, and possibility of increase in the left over from the cloth. The current loss level from the baseline setup was around 15%, 70% of which was lost during the cutting process.

After an advanced (automated) computerised marker development has been introduced the company was able to decrease both material cost and time. By improving the computerization of the marker development, the reduction of material waste can be established, leading to 2% increase in raw material utilization. The company was able to reduce 2% of their formerly generated solid waste from left over cloth, which is equivalent to 16,620 m of cloth (seven tons of cloth) with a cost saving of JOD 21,052[9].

Assessment for the factories in HIE: Reduce manufacturing waste at the factory level

To assess this circularity option at the factory level, the following guiding questions were followed in the survey:

Guiding questions for the assessment:

- Have the company or companies done any waste audits?
- Have they collaborated with any cleaner production consultants?
- Have they worked on reduction of roll-ends and garment cuts?
- If so, how much of waste generated per amount of transformed material can be avoided?
- Is it allowed by the international brands, clients to reuse the overproduction and deadstocks?
- Do the international brands impose some waste reduction targets or green manufacturing standards?

Apply innovative CAD cutting devices

For the case of HIE the interviews have shown that the waste generation on the cutting floor seems to be already within the usual range[10]. According to the American Association of Textile Chemists and Colorists (AATCC), around 10 – 25% of the fabric input is usually wasted as fabric trims. In HIE approximately 16% of their input material becomes waste as part of the cutting process. This is most likely due to CF being comparatively well equipped with state-of-the-art cutting devices. In the case of some of the smaller RMG factories in the cluster, the use of state-of-art cutting machines, innovative patterns or performance techniques may help to further reduce the waste of fabrics. In addition, skilled operators and good maintenance and housekeeping will also help to minimize the waste production.

[9] SwitchMed and UNIDO 2019.

[10] Jadwani 2019.

Avoid overproduction and deadstock

According to the available results from the survey, overproduction and deadstock are relatively limited in HIE. For instance, among the interviewed factories, three stated that even if fabric rolls have defects, they remove the respective part but use the rest of the roll as planned. Also, four factories mentioned that they can notify their supplier and return fabric rolls in case they are defective. This shows how good coordination and communication with the respective customers can achieve a precise planning of needed fabric surface, reduce false sample making, improve cutting patterns, sewing and assembly. Such practices could be upscaled for further decreasing waste from deadstock.

Apply eco-design principles (e.g. in the design stage) to optimise resource use

To avoid excessive resource-use, the producers should try to work together with their customers (brands) on eco-design principles and sustainable designs including recyclability and eventually also repairability (design for disassemble, reassembly and recycling).

4.1.2 Collection and separation for recycling at factory level

Globally, only 1% of fibre input is recycled back into garment production. It is clear that there is much potential for circularity in this industry.

One of the most relevant criteria for a waste exchange is the **economic value** of the waste for the potential receiving partner. The value for a further use as a raw material depends on the cleanliness and homogeneity of the fractions. Monofibre fractions are preferred without impurities of other fibre types and without additives or other environmental burdens. Most of the time, the cutting waste is free of threads from other materials (e.g., cotton fabrics are sewed with polyester threads). So, the waste generated while sewing and during assembly will be less suitable for a direct recycling due to the different fibre threads and accessories added.

Coloured fabrics should be sorted. Often coloured fabric residues must be treated to remove the dyestuff and the auxiliaries before getting reused after mechanical treatment as fibre or after a chemical treatment as monomer for re-spinning.

The **technical feasibility** and availability of recycling facilities is a limiting factor for an economic sound textile post production waste recovery. The logistics for smaller quantities of post-production textile waste to central recycling and processing units will limit the economics.

In all cases **compliance to regulatory requirements** like customs and waste management regulations must be followed.

The theory behind mechanical waste recycling

Mechanical recycling of textiles tears down the fabric back into fibres. It extracts the fibres by the help of shredding and carding from the fabric. This fibre can be spun to make yarn for either woven or knitted fabric. Mechanical recycling is best used for the mono-fibre fabric of cotton.

The first step is the shredding of waste fabric into smaller pieces which are then treated by a garnett machine for fibre extraction. These machines perform heavy and rough carding actions by tearing the fabric with opposite sets of strong sharp teeth transforming it to its component fibres.

The fibres collected are then mixed with virgin fibres with higher length in different blend percentages. Fibre length is the most important factor for the quality of the yarn. Modern garnett machines can recover fibres of the length 2 cm and above.

The mechanical textile waste recycling is done most of the time by specialised recyclers who operate the necessary equipment and have access to the recycled fibres' market or operate their own re-spinning technologies.

If waste can be appropriately separated within the manufacturing facility, textile recycling companies can buy and recycle them to produce recycled/regenerated fibres. This works very well with 100% pure cotton or polyester but is also applicable to blended materials like polyester/cotton.

In the following, **two sorting technologies** are described, which are mostly applied for post-consumption waste recycling.

- **Fibersort**
  Fibersort is an automatic sorting system of mixed post-consumer textiles. It automatically sorts large volumes of mixed post-consumer textiles by colour and fibre type using near infrared spectroscopy (NIRS) which allows the detection of garments from cotton, wool, viscose, polyester, acrylic and nylon. The sorted fibres have a low level of contamination and can serve as reliable, consistent input materials in mechanical as well as chemical recycling for high-value textile to textile recycler [11].

- **Textiles4Textiles**
  Textiles4Textiles (T4T) is another NIRS sorting technology that separates clothing items which was developed by Wieland Textiles and the Laserzentrum Hannover (LSH) [12]. It can separate used textile materials according to fibre composition and colour allowing the separation of 300 fractions. In case of sorting by colour, there is no need for bleaching or re-dyeing before the subsequent recycling stages avoiding chemicals and thus environmental benefits. Large facilities, investors and demand for unmixed used clothes will be necessary for market penetration of these technologies [13].

Case Study: Shreeji Cotfab

©Mel Poole for Unsplash

Shreeji Cotfab is a mechanical recycling company dedicated to the selling of recycled yarns for both knitting and weaving. Placed in India, they collect factory waste from garment manufacturers from Vietnam, Indonesia, and other middle eastern countries to process the waste into recycled yarn. Their process of textile recycling consists of shredding the fabric to extract out the fibres which are then mixed with a suitable percentage of virgin fibres so that the yarns made are of the much finer count. The yarns made is most suitable for knitting but for woven fabric, these yarns can only be used in the weft as the tensile strength is not enough to be used for warp. Use of these yarns can drastically reduce the price of the fabric made[14].

[11] Morton Hemkhaus et al. 2019.

[12] David Watson, Maria Elander, Anja Gylling, Tova Andersson and 2019.

[13] Morton Hemkhaus et al. 2019.

[14] Saha 2020.

The theory behind chemical waste recycling

Chemical recycling are processes to depolymerize / dissolve the fibre from the fabric into monomer / solvent form, either to make new fibre compound of it or extract one compound from a mix. The output products have often a similar quality as the virgin material.

The operation at factory level is difficult because most of the technologies are still in an early stage of development and need a critical mass of input material to be economically viable. On the other hand, the investment is high. There are some upcoming concepts which are as small that they might be applied on factory level. One of the promising concepts is green machine, developed by HKRITA with support from the H&M Foundation. It is the world's first technology that can recycle blend textiles at scale, without any quality loss.

In the following, **four chemical recycling solutions** are described as well as a case study, which are currently applied for post-consumption waste recycling.

- **Infinited Fiber (Relooping Fashion Initiative)**

  A so-called "infinited fiber" was developed by the VTT Technical Research Center of Finland together with the Infinited Fiber Company which got established in this context. It is recycled fibre produced from cotton rich textile waste and other biomaterials like wood which claims to be infinitely recyclable. For its production, a carbamate cellulose dissolution technique constitutes the centrepiece of the process and common methods from the pulp industry to remove polyester residues from the cotton[15]. The fibre has the same quality as a typical viscose fibre, but additional environmental benefits exist in comparison to viscose manufacturing. For instance, not only does it need one third less CO2-equivalents and 98% less water but it also allows the avoidance of harmful chemicals usage like carbon disulphide[16].

- **re:newcell pulp**

  A special pulp was developed by the company re:newcell at the Royal Institute of Technology in Stockholm, in partnership with SKS Textile and H&M. In the re:newcell process post-consumer garments and textile production waste with high cellulosic content, like cotton or viscose are shredded, de-buttoned, de-zipped, de-coloured and turned into a slurry, from which contaminants and other non-cellulosic content are separated. The product is then dried to produce Circulose®, a branded 'dissolving pulp' made from 100% recycled textiles. The sheets of Circulose® are finally packaged into bales and fed back into the textile production value chain where it can be used as a biobased equal-quality replacement for virgin materials like cotton, oil, and wood[17]. No harmful chemicals are needed in the process and the produced fibre has at least the same quality of a virgin fibre. In case of pure cotton, no addition of virgin fibre is necessary and close to 100 percent recycling can be achieved. Although the output fibres are biodegradable, the process is still energy intensive due to the drying process but does not exceed the energy demand of conventional viscose production according to interviewed experts[18].

- **Refibra (Lenzing)**

  The Austrian company Lenzing uses undyed cotton pre-consumer waste as input for their fibres. It replaces part of the wood in pulp fibre production by integrating recycling material in the company's conventional Lyocell production process. According to a study of 2019, the fibre quality is the same as for raw material from wood if undyed, homogenous pre-consumer waste is used. However just 30% in recycled raw materials usage is possible in Refibra

[15] VTT Technical Research Center Finland 2017.

[16] Morton Hemkhaus et al. 2019.

[17] Re:newcell 2022.

[18] Morton Hemkhaus et al. 2019.

fibres. Considering that Refibra fibre is mainly used in addition to virgin cotton, the actual content of recycled fibres is even lower. Research is continuously conducted in order to increase the recycled content and on the utilization of post-consumer waste which is stated as a long-term goal by Lenzing [19].

- **Innovative chemical polymer recycling (Worn Again)**

  With an innovative chemical polymer recycling approach, the company Worn Again converts polyester and polycotton blended textiles, and PET plastic, at their end of use, back into circular raw materials. The company is working together with brands and retailers such as H&M and Puma. The process begins with the separation and recapturing of polyester as well as cotton, followed by different processing approaches depending on the fibre type. Polyester is dissolved, embedded contaminants are extracted and a resin as the intermediate product is produced. The resin is then processed into a polymer and converted into virgin equivalent polyester. Although, the innovative aspect of the process is that polyester is not depolymerized into monomers but recaptured directly, thus leading to energy savings, the energy consumption is still comparatively high. In the case of cotton, dissolving takes places accompanied by the decoupling of dyes as well as contaminants and is followed by separation to produce a pulp, which is equivalent to viscose. 20% of impurities can be filtered out and a broad range of inputs is possible as pure and blended materials can be used.

Case Study: Green Machine by HKRITA

©H&M Foundation

The green machine licensed by HKRITA is a very time efficient and cost-effective technological solution for chemical recycling. It uses only heat, water, pressure, and a biodegradable green chemical. Based on this chemical and hydrothermal treatment under pressure this approach is able to recycle cotton and polyester blends into new fabric and yarns. This solution is modular which means it can be right-sized for any factory or set up. The Green Machine generates no secondary pollution since it's a closed loop where the water, heat and chemicals are used again and again. The output is long and good quality polyester fibres which can be used to make new garments. The cotton is extracted as cellulose powder, which can be used in multiple ways for example making new garments[20].

Assessment for the factories in HIE: Collection and Recycling

To assess this circularity option at the factory level, the following guiding questions were followed in the survey:

Guiding questions to ask for the assessment:
- Is the waste separable (how much cotton and polyester)? - Is collection and sorting carried out? - Do the company or companies have the required machinery? - What recycling technologies are available to the company or companies? - Are there any downcycling opportunities (for example insulation material)?

[19] Morton Hemkhaus et al. 2019.

[20] H&M Foundation 2021.

- Do the international brands suggest recycling targets? What is their engagement at the end of life of the product?
- Is there a recycling target or action plans considered for the RMG sector or the IEs in Jordan?
- Are there any investors (EBRD, EIB, Bank of Jordan) considering investing in the collecting, sorting, recycling infrastructure in the region?
- Is the municipality asking for a fee to pay for the disposal of the waste from the company or companies?
- What is the level of capacity and interest in the municipality for collaboration to manage the post-industrial waste in partnership with the company or companies?
- Is the composition of waste suitable for treatment by the latest chemical waste recycling solutions?
- Are the factories ready to invest in innovative chemical recycling processes?
- Would they participate in joint operations and collecting systems for chemical recycling processes?
- Is there an understanding within the companies about the advantages of chemical recycling processes?

Collection and sorting, by colour, type of fibre, size of cuttings

Currently waste separation at HIE factories from the RMG sector is limited to separating organic, and unseparated factory waste including mostly fabric together with some packaging material such as paper and plastic. The first and most important step for mechanical recycling is the separation of fabric waste from packaging waste.

Further, a consequent pre-sorting of fabric at the factory site by colour, type of fibre and size of cuttings improves the direct reuse or recycling of the fabric waste and raise the economic value of the fractions. Besides manual sorting and sorting technologies as described above can be applied.

Fluffing or mechanical recycling at the factory level

If the separated fabric waste reaches a certain purity and quality through sorting, it can be fluffed or mechanically recycled for further usage. CF at HIE already operates a fluffing unit (around 1 tonne / day) at factory level. Currently, the product is sold and used outside of the cluster for manufacturing downcycled products. Since a vast majority of the RMG factories in HIE uses woven fabrics as input material and does not operate a fully integrated production line, it seems unlikely that the fluffed or mechanically recycled material can be reused directly within the factory. One knitting factory may represent an exception as they use yarn as input material. However, currently there is no yarning factory operating in HIE, since all HIE manufacturers buy-in fabric and turn it into RMG.

Chemical recycling at the factory level

The structure of most RMG manufacturers at HIE may not be appropriate for the introduction of chemical textile recycling processes. The generation of textile waste within most production units will not allow an economically viable operation of chemical recycling processes, due to lack of economy of scale, with the excpetion of CF which generates significatnly higher amounts of waste. But even in the case of CF, it must be noted that chemical recycling would allow the production of recycled yarn, whereas the RMG factories including CF do not have a fully integrated value chain yet. This means that CF currently purchase finished fabrics instead of operating weaving or knitting machines in HIE themselves, hence recycled yarn is not a material that CF could directly use at scale as an input material for their current production line.

4.1.3 Upcycling at factory level

The theory behind this circularity option

Upcycling reuses materials that may otherwise end up in landfills in creative and innovative ways – producing original often one-of-a-kind items from what many consider to be waste. It is a way for companies and designers to be more efficient with leftover materials. The benefits of upcycling include resource conservation, lower carbon footprints, energy saving, and less use of landfill space.

For designers, upcycling presents an opportunity to practice creativity skills, but also to reduce impact on the environment, simply by reusing their own or others' waste. Giving a second life to textiles can result in one-of-a-kind items as well as reproducible products. Another method is that of deconstructing and recombining waste products, so that the parts are reused but in different ways. This can be done by using old garments, but also leftover swatches, production off-cuts and end-of-roll textiles.

Case Study: Bunko Junko	
 ©Bunko Junko	With her venture, Bhavini Parikh is preventing thousands of kgs of fabric waste from reaching the landfills. This is done by re-purposing the fabric to create the fashion brand – Bunko Junko. Bunko Junko diverts the scrap generated in textile manufacturing units away from landfills and into its design space. The creative designer and her team of dedicated designers create extraordinary products out of the textile scrap, literally transforming it from pieces of unrelated fabric to a fashion statement. Although formally registered in 2017-18, Bhavini and her team have been upcycling the fabric for the last three years and the customer base is growing.[21]

Assessment for the factories in HIE: Upcycling

To assess this circularity option at the factory level, the following guiding questions were followed in the survey:

Guiding questions for the assessment:
- Is the waste characteristic / composition created in the company and companies suitable for upcycling? - Are there interested parties (designer, SME, start-ups) which wants to use the post-production waste of the companies? - Are HIE industries interested to extend their portfolio by upcycling initiatives? - Is there a market for post-production waste in Jordan for upcycling purposes? - How such a market could be stimulated?

[21] Hetal Mistry 2020.

Re-cutting and sewing to lower sized products in the factory

In case of the production deadstock and assembly waste, a culture of further use and upcycling should be developed by the RMG factories in HIE in order to create best added value out of the used resources re-cutting and production of lower sized products for the local market. If collected and sorted appropriately, the factory can use bigger cuttings for own upcycling activities. One of the factories[22] already stated to keep defective rolls after delivery for reuse. Five of the factories further agree that fully manufactured RMG that get rejected in final quality checks are sometimes fixed and sold as quality B products. To develop upcycling opportunities the factories should cooperate with dedicated partners, designers and appropriate star ups so far they don't can or want to develop own capacities withi their factories.

4.2 Circularity options at cluster level

Sharing of information and best practices amongst different actors such as the textile producers in HIE, textile association, recyclers and waste ternsporters is particularly important in order to advance circular practices in the textile industry. At the supplier-level (i.e. textile manufacturers) trading platforms for off-cuts could further curb the generation of pre-consumer textile waste.

The factories in HIE need to have an overview about the products, processes and necessary raw materials of the different branches and enterprises within HIE. This may lead to an exchange of information about business opportunities. Such waste exchange models can be systematically promoted by the industrial estate management. An ongoing project by GIZ on the transition of HIE into an eco-industrial parks is laying the foundation for providing such an overview to the factories.

4.2.1 Collection, separation, and recycling at cluster level

The theory behind this circularity option

On a cluster level a systematic collection system can help improve the efficiency of the textile waste management through standardised containers for the different pre-sorted fractions, which meet the specification of recyclers. The harmonisation between collectors, transporters and recyclers is the key to reduce the amount of waste to be transported to the landfill. These three levels of waste handling can also eventually be coordinated and facilitated by an experienced waste management broker, who coordinates the communication and economic setup between the waste producers, the potential users, recyclers eventually also upcyclers and traders of uasable fractions . Such a coordination should lead then to a reduction of efforts and cost of the waste management operations.

Eventually there is also the need for further orientation by government agencies and the estate-management to stimulate the reuse of waste fractions through incentives and regulations. This may lead to the need to modify the existing custom-regulations to get permission for recycling and upcycling of post production waste fractions.

[22] Galaxy Fashion

Assessment for the cluster: collection, separation, and recycling

To assess this circularity option at the factory level, the following guiding questions were followed in the survey:

Guiding questions for the assessment:
- What are the different types of fabric used (with blend specifications)? - What are the amounts of the different fabrics used? - What are the logistic requirements for collection at separation at HIE (Land, built structures, transport, manpower)? - Can HIE accommodate the required infrastructure? - What is the investment required at the factory level to ensure optimum separation at sources? - What are the capacity building requirements for the implementation of effective waste collection and separation? - Which governmental agencies should be engaged?

Separated waste collection

Currently, textile waste is not properly separated from packaging waste at the factory level, nor can it be collected separated by the waste contractor. A separation process of the waste fractions at factory level should urgently be introduced and continued at cluster level. To achieve this, the fractions from all RMG factories at HIE should be transported separately and get offered separately at recycling markets. A weighing facility for the waste which is delivered from the factories to collection points would be required for documentation. In addition, the separation and collection processes at estate level requires an assessment of logistical requirements and available infrastructure. Moreover, the consolidated form of waste handling can help avoid and reduce landfill disposal and generate some income by marketing the more valuable fractions. According to the interviews the necessary space for waste separation, storage and collection at the estate levels exists already.

Develop a joint fluffing initiative within HIE

One potentially economically viable solution might be the joint operation of a fluffing operation treating the sorted fabric waste of all or at least several textile companies in HIE. This would allow the downcycling of non-reusable fraction into industrial rags, upholstery filling and insulation, which in turn will avoid dumping at Al-Ekeider landfill or incineration.

Recycling at the cluster level

If the fabric waste could be sorted and collected in a joint way by the HIE RMG cluster and other textile industries in Jordan, the feasibility of an economical solution for chemical recycling should be analysed. A technical solution for the introduction of recycling processes at the HIEs cluster level could be the so-called “green machine”, which describes a recycling machine applying hydrothermal treatment which was developed by HKRITA. A pilot plant which is already operating this machine can treat around 1,5 t/day of post-production fabric waste (see case study under 5.1.2 , p. 37). The upscaling of the process is under preparation but the investment costs still not reflect a level fit for a brought dissemination of the technology.

4.2.2 Upcycling at cluster level

The theory behind this circularity option

Upcycling is one of the most implemented circular business models in the South Mediterranean countries, but generally rather a small-scale initiative. There are several upcycling examples of garment, handbag, and accessories production. In those production processes, vintage materials such as; dead-stock fabric (including curtains, bed sheets, mattresses, and second-hand clothes) such as; landfill waste, and scraps from large garment and textile factories are used. Other textile products such as handcrafted products, rugs, ottomans, and pillows are also produced from similar sources.

There is great potential for replicating the existing upcycling examples in the South Mediterranean. Since upcycling is a handicraft with low entry-barriers, it is also a good opportunity to involve women in such businesses, who may sometimes face more challenges in acquiring a financial foundation for taking higher entrepreneurial risks. In terms of increased value added and larger businesses, technical and design assistance may be required for interested companies, designers and start ups.

Another option is to cooperate with local or international brands and retailers to supply them with upcycled textile products for certain collections with special environmental and social concepts[23].

Assessment for the cluster: Upcycling

Social entrepreneurship on upcycling at the cluster level

The cluster management could develop initiatives with SMEs and start-ups to use large and medium sized cuttings to produce new products. The companies which have business relations to designers and creative SMEs can develop business cases to create added value out of large and medium sized cutting swatches or unfinished assembly waste in form of new and unique products.

Case Study: Green Fashion	
 ©Green Fashion	Green Fashion is an Egyptian start-up that collects cuttings from RMG factories and upcycles them into fashionable products like bags, jackets or jeans. The start-up also uses post-consumer waste to manufacture products with higher value creating their own biodegradable clothes dyes that are sold to factories. The start-up also empowers single mothers and female workers in Bel Misht village by providing work opportunities and giving them a fair wage to enhance their lifestyle[24].

[23] SCP/RAC and BCSD 2020.

[24] ENI CBCMED 2022.

4.2.3 Industrial symbiosis (material exchange) at cluster level

The theory behind this circularity option

The material exchange amongst companies of HIE cluster or also beyond the estate can provide the opportunity to transform waste into new resources and raw materials of another manufacturing process of the same or another industry.

The results of the interviews and investigations of RMG factories in HIE don't provide many indications for symbiosis potentials. It became apparent, that no factories exist which can use unprocessed textile waste as direct input for their manufacturing process. In few cases such as the chemical and construction sector there might be possibilities of processing the textile waste to integrate it into their production. For a identifying case with even higher potential of industrial symbioses, the research area might need to be extended beyond HIE.

Case Study: RESYNTEX
RESYNTEX is a project funded by the European Commission, which was set out to design, develop and demonstrate an industrial symbiosis opportunity between textile waste and the chemical industry. This approach is designed to achieve the chemical/enzymatic transformation of textile waste into a form which facilitates the uptake of the waste as feedstock by the chemical industry, producing high added value chemicals. This ensures competitive production costs for the chemical market. While this is a post-consumer project which considers the whole value chain, it may be further explored for implementation on post-industrial waste, improving and automatizing the industrial sorting, demonstrating the production of the transformed textile components and the symbiosis with the obtained chemical products. [25]

Case Study: FaBRICK

FabBRICK is the first brick entirely made of recycled textile and comprises promising properties by being insulating, aesthetic and load-bearing. In that regard, FabBRICK can be used in various interior design projects: seats, walls, retail furniture and many more. The shredded textile are mixed with a binding material and is compressed in a mould, resulting in a material similar to clay that will be shaped by the mould. The follow various steps:

- Step 1: Accepting discarded clothes sorted by colours.
- Step 2: For each project, the customer chooses the format the colour.
- Step 3: Shred the textile to obtain fibres.
- Step 4: Make the glue.
- Step 5: Mix the glue and the fibres by hand.
- Step 6: Incorporate the mixture to their patented machine.
- Step 7: Start the machine in order to compress the mixture inside the mould.
- Step 8: The brick dries in ambient air between 10/15 days.
- Step 9: Use these bricks to create furniture and partition walls too.

[25] European Commission 2019.

Assessment for the cluster: Industrial symbiosis

To assess this circularity option at the factory level, the following guiding questions were followed in the survey:

Guiding questions for the assessment:

- What are the existing industries at HIE?
- What are the main products coming out of non-textile industries in the estate?
- Can textile waste be utilized as an inflow for production in non-textile industries in the estate?
- What are the required process modifications, if any, for integrating textile waste into non-textile industries in the estate?
- What are the required investments in terms of infrastructure, process improvements, capacity building?
- What are the existing opportunities for material exchange within the textile cluster?
- Can an information and dialog platform be developed for the stimulation of knowledge and information exchange?

Industrial symbiosis with chemical and construction sector

The chemical industry and the construction industry are promising fields of textile waste conversions. A certain scale of economy will be needed especially for chemical conversion processes of synthetic fibre back to monomer stage.

Incineration and energetic use of textile waste is not following the logic of a circular economy, making them a solution of last resort. Lafarge, a Jordanian cement manufacturer is considering to conduct a pilot in Jordan which has been carried out in Egypt, whereby textile waste is used as a source of energy for cement manufacturing.

4.2.4 Waste to energy at cluster level

Thermal recovery of unwanted textiles not suited for the previously discussed options (i.e. mechanical recycling and upcycing) can be considered a viable alternative to landfilling[26]. The thermal decomposition methods include incineration and pyrolysis. The key difference between incineration and pyrolysis is that incineration is the combustion of organic matter in the presence of oxygen whereas pyrolysis is the combustion of organic matter in the absence of oxygen.

As the composition of the textile waste at the HIE is mainly mixed and has high polyster content, the calorific value might be acceptable for incineration. Though incineration process of textiles is often difficult to handle. Investigations of cotton and polyester textiles incineration showed that textiles can cause irregular behavior of the temperature profile and the ignition rate. Textile waste can also cause problems in the incineration process if they are too long or they might cause fires outside the incinerator. However, when textiles were mixed with cardboard; the burning behavior of the textiles might become more uniform.[27] As the World Energy Council cautiously states, in a 2017 report, “These technologies are useful as long as the combustion plants are properly operated and emissions controlled.”[28]

[26] Jaeanger, et. al. 2022.

[27] Youhanan 2013.

[28] Royte 2019.

Another expanding technology that might be relevant is pyrolysis, in which plastics are shredded and melted at lower temperatures than gasification and in the presence of even less oxygen. The heat breaks plastic polymers down into smaller hydrocarbons, which can be refined to fuel. Pyrolysis can handle multi-layered materials that most mechanical recyclers can not. Pyrolysis can be carried out via thermal or catalytic routes. Thermal pyrolysis produces low quality liquid oil and requires both a high temperature and retention time. In order to overcome these issues, catalytic pyrolysis of plastic waste has emerged with the use of a catalyst. It has the potential to convert 70–80% of plastic waste into liquid oil that has similar characteristics to conventional diesel fuel.[29] For example, ASERT Tech uses Thermal Catalytic Degassing Technology (TCDT), in which waste materials are converted into high-calorific gas, high-quality oil, activated coke and fertilizer, claiming to be without pollutants or emissions.[30] On the other hand, critics call pyrolysis an expensive and immature technology, with startups that have come and gone over the years, unable to meet their pollution control limits, or technical and financial goals.

All in all, while a waste to energy plant can supply fuel or electricity for industrial processes in the industrial estate (such as steam machines), the environmental and operational risks of this option have to be well assessed. Indeed, recycling consumes less energy and imposes lower environmental burdens than disposal of solid waste materials via landfilling or incineration, even after accounting for energy that may be recovered from waste materials at either type disposal facility.[31] Last but not least, once investment in such a plant is done, this infrastructure has to be fed with continuous flow of low-quality textile waste incentivising the industry to leak materials out of the system and not to loop or circle them back into the economy.

[29] Miandad 2016.

[30] Technology Asert 2022.

[31] Morris 2005.

5 Conclusions on Circularity Options

This chapter concludes the circularity options and provides an overview of measures for implementing the options. The feasibility of each measure is briefly evaluated. In addition, the enabling factors that would need to be included for implementation are emphasized. An overview of the circularity options and their measures can be taken from Figure 13.

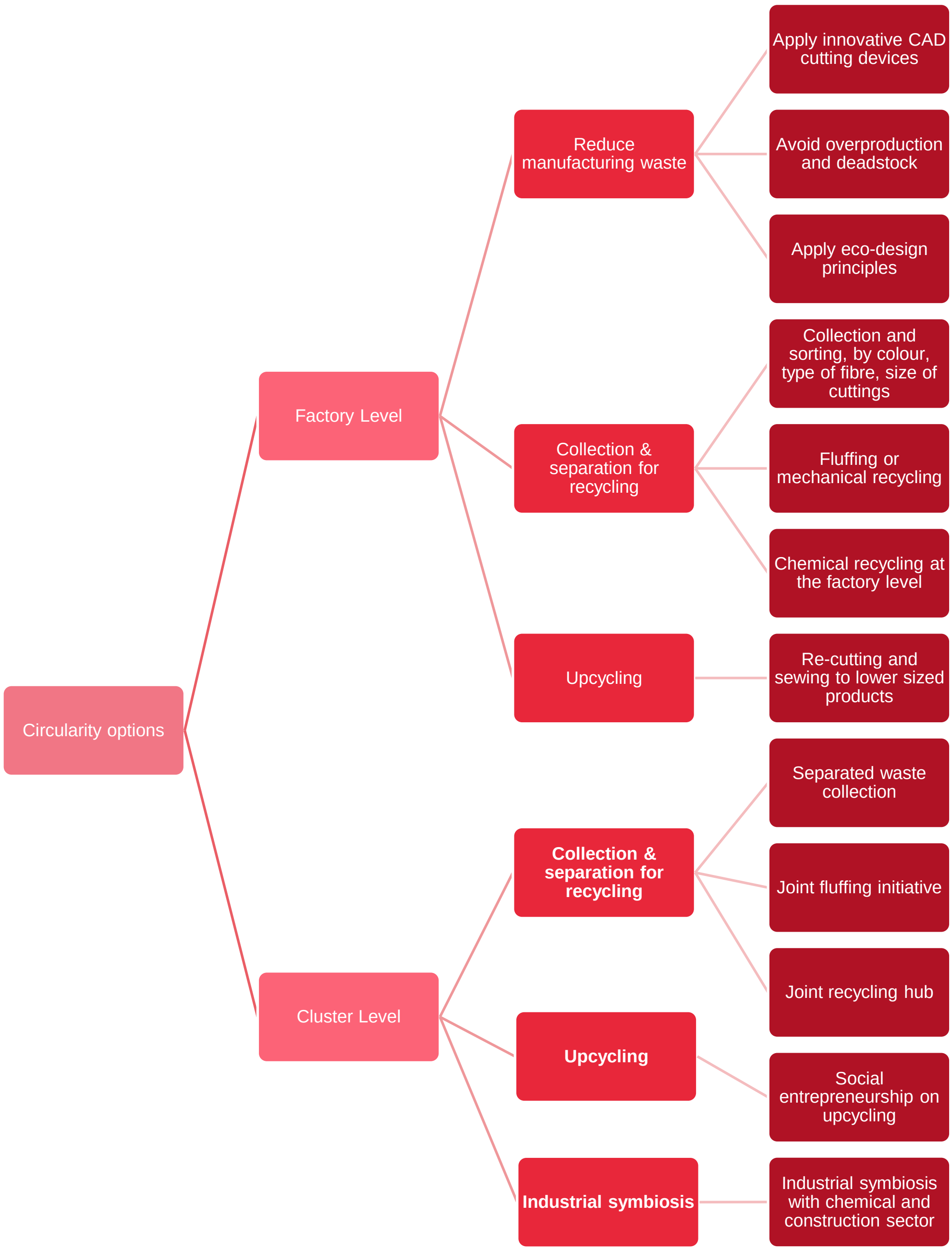


Figure 13: Overview of circularity options including potential measures

At the **factory level**, the feasibility and impact of circularity options depend on a variety of factors as illustrated in Table 9.

For **reducing manufacturing waste** (1) one technical solution is a more material-efficient cutting device which improves waste generation on a moderate level, but it would also require financial resources and technical capacities. A solution which would require more capacities on coordination would be to hire a specialist that minimizes overproduction and deadstock by improved material planning. This measure could have a moderate effect and can be considered quite feasible as the financial implications are comparably low. A strategic solution would be to focus on and work with clients that are ambitious in implementing zero-waste measures by implementing eco-design principles. This measure would nevertheless be rather limiting for the factory as there are only few brands that prioritize zero-waste and eco-design over other factors such as productivity and speed, despite a potentially low sustainability impact.

In order to implement the **collection and separation for recycling** (2) first of all, collection and sorting would be an important measure to apply which could be rather impactful and also feasible to a medium level, considering that sorting would be handled manually. Technical sorting would meanwhile require high financial resources. High impact could also be achieved if factories would be able to establish fluffing or recycling facilities at their factories. However, both would require high financial resources which are unlikely to be covered by a single small- or medium sized factory as well as to find a buyer for instance a weaver, in case the yarn cannot be used within the factory directly.

Implementing **upcycling** (3) for instance by re-cutting and sewing unusable fabric pieces into other products would be quite feasible, as it only requires hiring extra staff for this task, though the process would not be particularly time-efficient and could only stay at a small scale.

Table 9: Feasibility and impact conclusions on circularity options (factory level)

Circularity option	Solution	Enabling factors	Impact	Feasibility
(1) Reduce manufacturing waste	**Apply innovative CAD cutting devices**	- Financial resources are available - Technical capacities are available	●●●○○	●●○○○
	Avoid overproduction and deadstock	- Coordination resources and financial resources thereof are available	●●●○○	●●●○○
	Apply eco-design principles	- Zero-waste ambitions are shared by client (brand) - Technical capacities are available	●○○○○	●●○○○
(2) Collection & separation for recycling	**Collection and sorting**	- Coordination resources and financial resources thereof are available	●●●●○	●●●○○

	Fluffing or mechanical recycling	- Financial resources are available - Interest of buyers	●●●●○	●○○○○
	Chemical recycling at the factory level	- Financial resources are available - Interest of buyers	●●●●○	●○○○○
(3) Upcycling	**Re-cutting and sewing to lower sized products**	- Coordination resources and financial resources thereof are available - Technical capacities are available	●○○○○	●●●●○

At the **cluster level**, the feasibility and impact of circularity options also depend on a variety of factors as illustrated in Table 10.

For implementing **collection, separation, and recycling** (4), the waste collection would need to be first established. As collection points are already in place, this measure would require financial resources by various factories to establish a centralized sorting facility in the cluster, which would additionally require the coordination between the factories and management of the respective sorting facility. However if applied preparatory to recycling this could have a comparatively high long-term circularity impact. Same applies for establishing a joint fluffing initiative as well as a recycling hub in the HIE. Such measures would require the financial commitments through partnership of factories in HIE as well as high organizational resources. Hence, the feasibility of such measures has to be considered low due to its high complexity.

Upcycling (5) could also be implemented at the cluster level, by fostering social entrepreneurship for upcycling within the cluster. For this option, the creation of an interesting business environment for entrepreneurial activities would need to be established within the cluster. Such entrepreneurs would then need to coordinate his or her supply from different factories to create a financially stable and scalable upcycling start-up.

As there are a lot of dependencies on the entrepreneurial activities in the region the feasibility would require further assessment, though the impact could be medium to high, as it could achieve social and cultural improvements within the cluster.

Finally, for creating an **industrial symbiosis** (6) it is necessary for the RMG factories to identify and approach one or several adequate symbiosis-partners from the RMG or another sector, with whom they could establish a regular material exchange. Although this would require high initial organizational capacities, this option could have a long-lasting effect and high circularity impact.

Table 10: Feasibility and impact conclusions on circularity options (cluster level)

Circularity option	Solution	Enabling factors	Impact	Feasibility
(4) Collection & separation and recycling	**Separated waste collection**	- Financial resources are available - Coordination resources are available	●●●●○	●●○○○

	Joint fluffing initiative	- Financial resources are available - Coordination resources are available	●●●●○	●●○○○
	Joint recycling hub	- Financial resources are available - Coordination resources are available	●●●●○	●●○○○
(5) Upcycling	**Social entrepreneurship on upcycling**	- Entrepreneurs are invited to cluster - Scalability - Technical capacities are available - Coordination resources are available	●●●○○	●●●○○
(6) Industrial symbiosis	**Industrial symbiosis with another sector**	- Interest for material exchange can be fostered - Scalability - Coordination resources are available	●●●●●	●●○○○

In conclusion, at both the factory and cluster level, different capacities are required to implement the proposed circularity options. Table 11 provides an overview of some additional criteria which need consideration for implementation. These proposed circularity options will be further assessed in detail in the form of businesses cases in the WP2 of the project.

Table 11: Additional criteria for implementing the circularity options

	Factory Level	Cluster level
Selection/ assessment criteria	1. Interest of factory to engage	1. Interest of various factories to engage
	2. Robust internal management systems (QHSE)	2.Established economic and environmental case for material exchange
	3. Significant production share	2.Established economy of scale case
		3.Logistical ease in terms of proximity of engaged companies
		4. Infrastructural readiness

6 Appendix A

	Organisation	Contact person
RMG manufacturers		
1	The Engineer company for clothes	Eng. Thaer Al Zoubi
2	Darb Al tabanah for clothes	Hiba Al Zoubi
3	Sanaa for clothes	Reem Al Omari
4	Al Thafer for clothes	Mohammed Hajjeer
5	Al Azya al Taqledeyeh for clothes	Ramdas Nair
6	Al Anaqa al Duwaleyeh for clothes	Mohammed Al Sharwan
7	Al Maseerah Company for textile	Ammar Al Taweel
8	Haifa Apparel	Ibrahim Egailan
9	Mojezet Al Aser	Walaa Khamayseh
Government Agencies		
1	HIE management	Eng. Hani Thiabat
2	Customs Department at HIE	Colonel Wasfi Al Mahasneh
3	Al-Ekeider Landfill Management	Eng. Ashraf Bani Hani
Other		
1	Waste transport contractor	Mohammed Al Darabseh

7 Appendix B

Textile Manufacturer Survey

Qualitative Questions
1. Can you walk me through the production process in your company?
2. What type of fabric are you using?
3. In case a roll is not accepted is it sent back to the supplier or into the landfill?
4. Are waste generated from Warehousing?
5. What do you do with the assembly and quality reject? Do the items rejected from assembling and quality check get "fluffed"?
6. Can you confirm if the company's process reflects flow diagram in the sheet "flow diagram"?
7. What is starting point of the value chain? Delivery of fabric? Or do many factories also process weaving/knitting?
8. What percentage of the waste makes up packaging waste (plastic and paper)?
9. What amount of fabric (in tonnes) comes into the/a factory?
10. How often are fabric rolls rejected?
11. In which quantities are fabric rolls rejected?
12. Is the fabric Imported or locally produced?
13. What other material volumes are there (buttons, rubber band, zippers). How much waste are generated from these materials?
14. When are orders cancelled by buyers at which part of the process does the waste mostly occur? Is it possible to reuse the material for another order?
15. How much packaging you need per role?
16. At which process does packaging waste mostly occur?
17. Regarding overproduction: Do buyers realize overproduction before or after packaging the final RMG?
18. Is the input (fabric) and output (waste) measured? How? In which unit?

19.	**Which are the most relevant factories for the cluster? Which share do they have?**
20.	**Which other sectors and factories are operating in the QIZ? Is co-processing (cement production) present in the QIZ?**
21.	**Would factories (textile or other) accept rejects from textile factories to process them? What is already being done in the past? What is the attitude for the future?**
22.	**If the material is dispatched does not pass the quality check, is it sent back?**
23.	**Is there an interest in investing in circular economy measures?**
24.	**Is the waste from factories classified as waste? If so, as what type of waste?**
25.	**To what extent are factories paying customs to transport waste out of the QIZ?**

Quantitative Data collection

	Fabric Waste Amount [kg/month]	Disposal practice	Plastic Waste Amount [kg/month]	Disposal practice	Paper Waste Amount [kg/month]	Disposal practice	Other Waste Amount [kg/month]	Disposal practice
Delivery & acceptance								
Warehousing								
Cutting								
Assembling/ sewing								
Quality check								
Packing of items								
Dispatching								

HIE Management Survey

1. What is the amount of waste produced daily in HIE?
2. How much of that waste is fabric (in percentage or weight)?
3. How much of that waste is plastic (in percentage or weight)?
4. How much of that waste is paper (in percentage or weight)?
5. How much of that waste is organic (in percentage or weight)?
6. Who picks up the different wastes (fabric, plastic, paper)?
7. Are there various different waste collectors or just one service provider?
8. Is waste from the factories separated (fabric, plastic, paper)?
9. Do collectors throw all the waste together into the vehicle?
10. Is the fabric waste mainly cutting waste or finished/partly finished garments?
11. Where does the majority of waste go to? How much waste is it daily?
12. Which are other destinations of the waste? How much (weight) waste goes there daily?
13. Are there any recyclers on HIE area? What do they process? How much do they process?
14. Are there companies which use waste from another factory as raw material? Who? How much (weight)?
15. Which company produces the majority of waste? How much (weight)?
16. Which company produces the majority of fabric waste? How much (weight)?
17. Which are the top 10 garment factories in HIE. What is their share in daily production volume (pcs/day) or in percentage?
18. What are the costs of waste pick-up in HIE?
19. What is already being done regarding waste minimization?
20. What is already being done regarding material exchange/industrial symbiosis?

Customs Department Survey

1. How much waste leaves HIE daily?
2. How much fabric waste leaves HIE daily?
3. How much fluff/fluffed fabric waste leaves HIE daily?
4. What are the costs of waste pick-up in HIE?

Landfill Management Survey

1. What is the amount of waste produced daily in HIE?
2. How much of that waste is fabric (in percentage or weight)?
3. How much of that waste is plastic (in percentage or weight)?
4. How much of that waste is paper (in percentage or weight)?
5. How much of that waste is organic (in percentage or weight)?
6. Who picks up the different wastes (fabric, plastic, paper)?
7. Are there various different waste collectors or just one service provider?
8. Is waste from the factories separated (fabric, plastic, paper)?
9. Do collectors throw all the waste together into the vehicle?
10. Is the fabric waste mainly cutting waste or finished/partly finished garments?
11. Where does the majority of waste go to? How much waste is it daily?
12. Which are other destinations of the waste? How much (weight) waste goes there daily?
13. Are there any recyclers on HIE area? What do they process? How much do they process?
14. Are there companies which use waste from another factory as raw material? Who? How much (weight)?
15. Which company produces the majority of waste? How much (weight)?
16. Which company produces the majority of fabric waste? How much (weight)?
17. Which are the top 10 garment factories in HIE. What is their share in daily production volume (pcs/day) or in percentage?
18. What are the costs of waste pick-up in HIE?
19. What is already being done regarding waste minimization?
20. What is already being done regarding material exchange/industrial symbiosis?

Waste Transport Contractor Questions

1. What is the amount of waste produced daily in HIE?
2. How much of that waste is fabric (in percentage or weight)?

3. How much of that waste is plastic (in percentage or weight)?
4. How much of that waste is paper (in percentage or weight)?
5. How much of that waste is organic (in percentage or weight)?
6. Who picks up the different wastes (fabric, plastic, paper)?
7. Are there various different waste collectors or just one service provider?
8. Is waste from the factories separated (fabric, plastic, paper)?
9. Do collectors throw all the waste together into the vehicle?
10. Is the fabric waste mainly cutting waste or finished/partly finished garments?
11. Where does the majority of waste go to? How much waste is it daily?
12. Which are other destinations of the waste? How much (weight) waste goes there daily?
13. Are there any recyclers on HIE area? What do they process? How much do they process?
14. Are there companies which use waste from another factory as raw material? Who? How much (weight)?
15. Which company produces the majority of waste? How much (weight)?
16. Which company produces the majority of fabric waste? How much (weight)?
17. Which are the top 10 garment factories in HIE. What is their share in daily production volume (pcs/day) or in percentage?
18. What are the costs of waste pick-up in HIE?
19. What is already being done regarding waste minimization?
20. What is already being done regarding material exchange/industrial symbiosis?

8 Appendix C

HS Codes used for the identification of the products entering HIE

HS Code	Product descriptions
50	Silk
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric
52	Cotton
53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
54	Sewing thread of man-made filaments, whether or not put up for retail sale
55	Man-made staple fibres
56	Wadding, felt and nonwovens; special yarns; twine, cordage, ropes and cables and articles thereof
57	Carpets and other textile floor coverings
58	Special woven fabrics; tufted textile fabrics; lace; tapestries; trimmings; embroidery
59	Impregnated, coated, covered or laminated textile fabrics; textile articles of a kind suitable for industrial use
60	Knitted or crocheted fabrics
61	Articles of apparel and clothing accessories, knitted or crocheted
62	Articles of apparel and clothing accessories, not knitted or crocheted
63	Other made up textile articles; sets; worn clothing and worn textile articles; rags

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