التعاون الألماني
DEUTSCHE ZUSAMMENARBEIT

Implemented by
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The Hashemite Kingdom Of Jordan
Ministry of Industry, Trade and Supply

Ministry of Environment

Business Case 4: Chemical Recycling for Fibre-To-Fibre Yarn Production

Introducing Circularity as a Business Opportunity to Jordan's Ready-Made Garment (RMG) Sector

BACKGROUND

The "Green Action in Enterprises" (GAIN) project, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) *GmbH,* works in close cooperation with the Ministry of Environment, the Ministry of Industry, Trade and Supply and other stakeholders towards the green industrial transition by introducing sustainable use and management of energy, water, and waste in the sector.

In Jordan, the garment manufacturers at Al-Hassan Industrial Estate (HIE) generate 35 tonnes of solid textile waste per day, which is being disposed of in municipal landfills. This textile waste is being 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 the long term. Based on collected quantitative and qualitative data, a list of circularity options was explored. **5 business cases** have been developed which provide marketable solutions for textile and garment waste minimisation, prevention, and revalorisation. The primary purpose of these business case is to identify opportunities to minimise textile waste, including recycling, upcycling, and reuse measures for factories in HIE.

Business Case 1:	Investing in Material Efficient Technology and Software
Business Case 2:	Mechanical Recycling for Industrial Symbiosis
Business Case 3:	Mechanical Recycling for Fibre-to-Fibre Yarn Production
Business Case 4:	**Chemical Recycling for Fibre-to-Fibre Yarn Production**
Business Case 5:	Upcycling with Social Entrepreneurs

BUSINESS CASE 4 RATIONALE

The business case on **chemical recycling for fibre-to-fibre yarn production** recommends the establishment of an onsite joint recycling hub in HIE which can be utilised to process all generated textile waste through chemical recycling. The establishment of this hub will reduce costs as chemical recycling would need high initial capital investments which could be shared by companies in a recycling hub. It will also reduce the costs of raw materials used by garment manufacturers and improve their production efficiency as well as reduce the environmental impacts since landfilling will no longer be necessary.

DESCRIPTION OF BUSINESS-AS-USUAL

CURRENT WASTE HANDLING PRACTICE

Garment manufacturers in HIE generate around 35 to 40 tonnes of textile waste daily, 70% of which is cutting waste of small and medium sized cuts.

This waste is disposed of by the factories in containers outside their premises without separation based on textile type and/or colour. The waste is then thrown in bulk in containers, which are then collected by a private contractor at HIE and transported to Al-Ekeider landfill.

Currently, factories at HIE do not implement any chemical recycling processes for fibres and there is no sorting or waste separation at the industrial estate level.

COSTS OF CURRENT WASTE HANDLING MODEL

- pick-up and landfilling costs: 4 JOD per tonne of textile waste

RISKS OF CURRENT WASTE HANDLING MODEL

- Penalties for noncompliance with current waste management regulations
- Increasing costs of waste handling and transport, e.g., closing of Al-Ekeider landfill for textile waste
- Costs of compliance with export market laws (e.g., EU supply chain due diligence)
- Opportunity loss due to high prices of raw materials which is being wasted

DESCRIPTION OF BUSINESS CASE 4

NEW WASTE HANDLING PRACTICE

This business case proposes to invest in a joint recycling hub for the entire textile cluster at HIE to implement chemical fibre recycling. The chemical fibre recycling processes need sorting by colours and fibre mixes. These pre-treatment steps are like the steps used for mechanical recycling processes: collection, mechanical removal of non-textile parts, sorting, fluffing and carding to a fibrous material. After the fabric has been opened (separated) to the fibre level, a series of chemical processes are applied to depolymerise/dissolve the fibre from the fabric into a monomer/solvent form either to make a new fibre compound or to extract one compound from a mix.

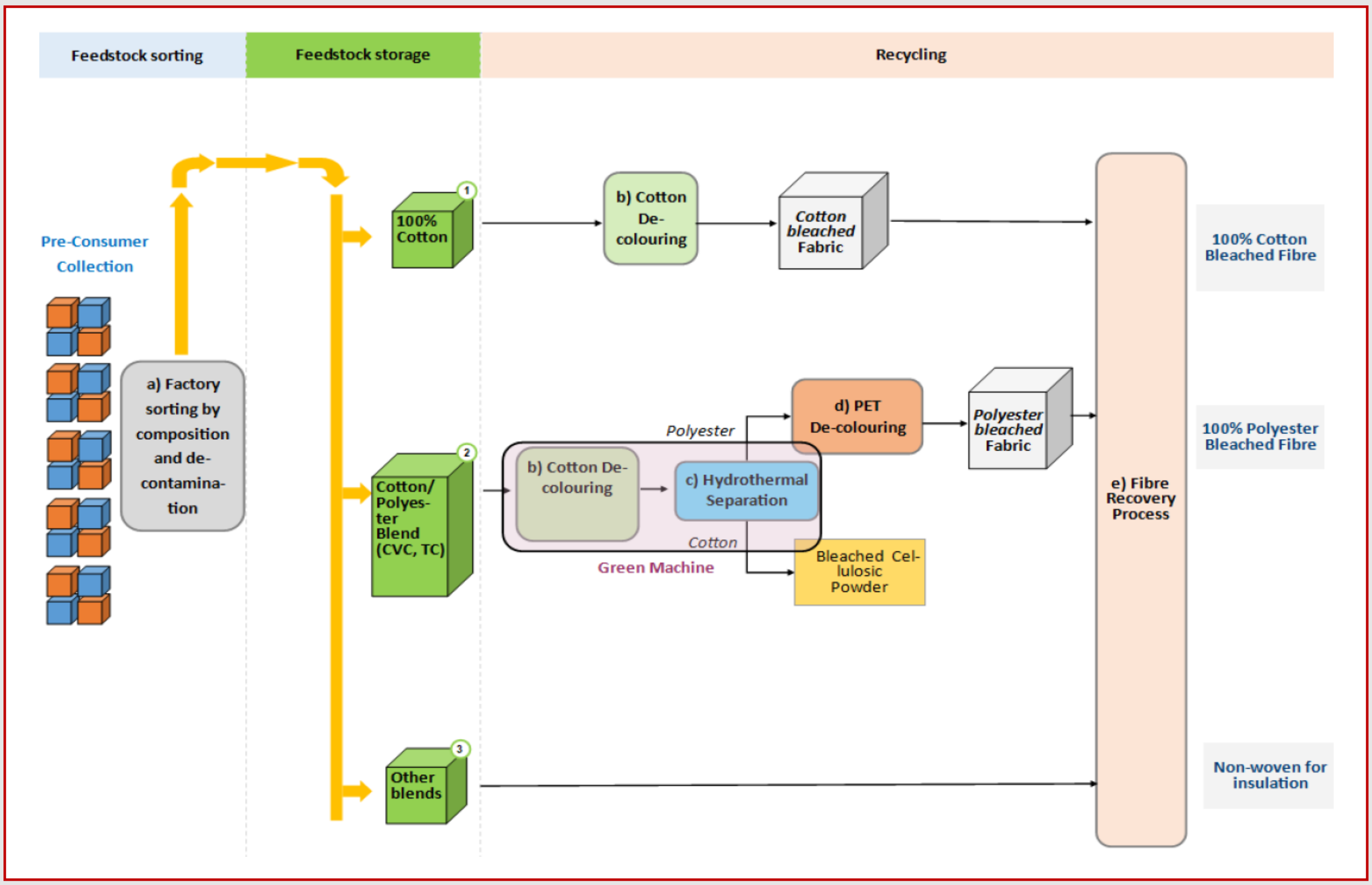
One must also distinguish the different chemical recycling processes:

- **Depolymerization processes** disintegrates the fibres to the monomer level.
- **Thermo-mechanical processes** melt them into a regranulated and/or new fibres. Thermo-mechanical processes are thermal recycling systems that melts a polymer, typically employed to permit polymer recycling, including polyester, polyamide, polypropylene, etc

- **Thermo-chemical processes** (another thermal recycling system) break them down into low molecular weight building blocks. This type of process is of importance for material recovery, more specifically for the recovery of base molecules (e.g., monomers, synthetic gas, oils) that serve as feedstock for the chemical industry.

According to a press release issued by the Hong Kong Research Institute for Textiles and Apparel[1], the "Green Machine" is a hydrothermal separation system developed in collaboration with the H&M Foundation. The hydrothermal separation system improves the feasibility of recycling of blended materials by selectively dissolving cotton into cellulose powders, which enables the separation of the polyester fibres from the blends. The separated polyester fibres are then ready for spinning and manufacturing into new garments. The whole process uses only heat, water and citric acid, a naturally occurring chemical found in lemon juice.

The Green Machine hydrothermal separation can process 1.68 tonnes of blended fibres per day over 3 shifts. In this process, it consumes 45.5 Kw per hour, 2.61 tonnes of water per tonne of textile waste, and requires chemicals at the cost of 276.8 USD per tonne of textile waste. It recovers more than 95% of the polyester fibre. Factories using seamless knitting technology can use the yarn which is produced in this process. The Green Machine can only process around 1,5 to max 5 tonnes of blended fibres per day.



Source: HKRITA Presentation recieved by adelphi 21 January 2022

[1] Source: https://www.hkrita.com/en/our-innovation-tech/projects/green-machine-phase-2

Practice Example 1:

The **Japanese Teijin Group** has developed a technology to mass produce a new version of an ultra-fine polyester, which is considered the world's first nano-fibre to be **made from recycled polyester raw materials**. It may be used for athleisure fashion and outdoor apparel. The yarn made from recycled polyester offers the **same functions as conventional** materials. The company will start producing the fibre in 2023.

Practice Example 2:

The **green machine by Hong Kong Research** Institute of Textiles and Apparel (HKRITA) is a technological solution for **chemical recycling**. It uses heat, water, pressure, and a biodegradable green chemical (citric acid based). Based on this chemical and hydrothermal treatment under pressure this approach can **recycle cotton and polyester blends**. This solution is modular which means it can be right sized for any factory or set up. The output is a **high-quality polyester yarn**. The cotton is extracted as **cellulose powder**, which can also be used in multiple ways, for example to make new yarn.

Practice Example 3

Re:newcell is the first large scale recycling processes of post-consumer textiles. It is a patented process turning cotton and viscose into high quality biodegradable dissolving pulp, from which new fibres and clothes are produced. A first scaled plant will recycle 7,000 metric tonnes of pulp per year at Kristinehamn, Sweden. A full-scale plant with 120,000 metric tonnes per year is planned to start operation in summer 2022 and will be the largest chemical textile recycling plant.

Practice Example 4:

The **Worn again process** uses a solvent technology to separate PET material from cotton fibres by dissolution, removal of dyes, catalysts and other organic additives. The PET fraction is converted into high quality PET resin chips for further use in the plastic industry or the production of new PET fibres. The cotton fraction is treated with different solvent to remove dyes from the cellulosic fibres, insoluble additives are filtered. The product is a cellulosic pulp which can be respun to Viscose.

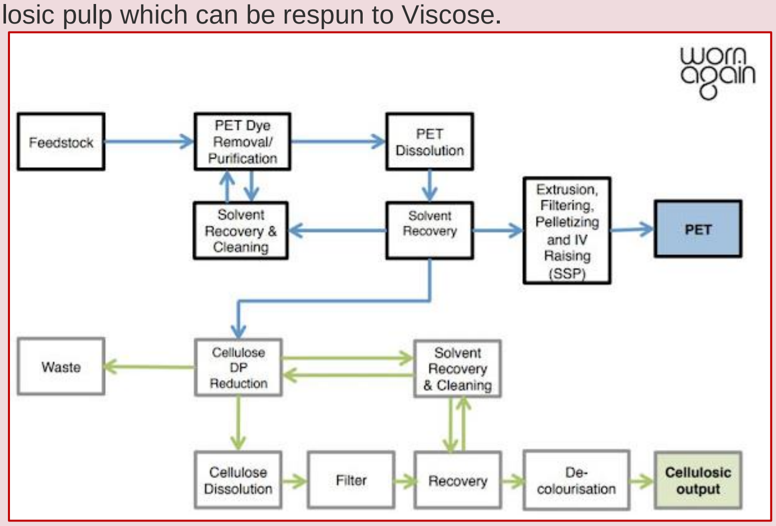


Image Courtesy: Worn Again | Source: GREENBLUE

BENEFITS OF IMPLEMENTING CHEMICAL RECYCLING FOR FIBRE-TO-FIBRE YARN PRODUCTION

- Reduced service costs for waste pick-up and handling
- New source of income for manufacturers from selling the recycled yarn
- Improved production efficiency for manufacturers using the recycled yarn
- Improved customer satisfaction since environmental requirements are complied with
- Improved inter-cluster collaboration through joint recycling
- Reduced material input due to use of recycled yarn
- Reduced material output as waste
- Job creation in recycling hub
- Sharing capital cost for recycling hub across the cluster
- Decreased CO_2 emissions and soil pollution due to less landfilling

Financial Benefits:

	Value per unit	Number of units	Total benefit
Cost savings on waste	4 JOD per tonne	1.68 tonnes per day x 365 days = 613,2 tonnes per year	2,452.8 JOD per year
Selling cellulose powder	Around 1 JOD/kg[2]	273 tonnes per year[3]	306,600 JOD
Selling recycled yarn	1500 JOD/tonne	*The percentage of recycled yarn that can be attained from the cellulose powder is still to be attained from the technology provider*.[4]	Data N.A.
Polyester (PET granulates)	565 JOD/tonne (800EUR/tonne[5])	273 tonnes per year	154,245 JOD
Job creation – enterprises	15 Jobs (5 operators /shift)		
CO2 emissions avoided	5.19 Kg CO_2/kg mixed fabric[6]	613,2 tonnes per year	3,182,508 tonnes CO_2
Total benefits			463,297.8 JOD

[2] Average price international market for cellulosic fibre, for example in the Indian cellulose market.
[3] Potential Amounts and quality of marketable products have to be further investigated with technology provider. The amount depends on the cotton content in the textile waste. Here we assume that the waste is 50% cotton and 50% polyester. Out of this, circa 10% might need to be cleaned up (e.g. dyes). This means circa 750kg cotton and circa 750kg polyester content can be recovered daily. It is important that the elastane content is below 5% for good functioning of the recycling process.
[4] The percentage of recycled yarn that can be attained from cellulose powder is to be attained from the technology provider

[6] Source: https://www.researchgate.net/figure/ndustrial-carbon-footprint-of-textile-fabrics-in-this-study-kgCO-2-e-kg_tbl1_303634993

COSTS AND CHALLENGES

Costs

- Costs of textile waste sorting and separation
- Costs for establishing the recycling hub
- Costs for operating and maintaining the hub
- Logistical costs for transportation of waste

Challenges:

- Mobilisation of initial investment funds
- Organisational challenges to motivate the collaboration within HIE to invest and operate a joint chemical recycling hub
- Mobilisation and development of technical know-how and workforce for setting up and operating a joint chemical recycling hub
- Verifiable data about potential revenues of the products celluloses powder / pulp and PET granulate / yarn are not available for the specific case. These need to be further investigated by technical experts.

Total costs: establishing a chemical textile recycling plant (1-unit Green Machine, capacity 1,68 tonnes/day)

-the used figures of the Green Machine process were provided by HKRITA -

	Cost per unit	Number of units	Total cost
Capital Expenditure (CAPEX)			
Machinery	around USD 1,500,000 /unit (1,065,000 JOD)	1 time investment	USD 1,500,000 (1,065,000 JOD)
Factory building	min. 200 m²	1 time investment circa 1.500JOD /sqm	282,000 JOD
Total CAPEX			1,347,000 JOD
Operational Expenditure (OPEX)			
Land Leasing	20 JOD/m²	200 m²	4,000 JOD/year
Power	45,5 KWh	24 hours/ 12 months	43,230 JOD 393,000 KWh/year
Water Consumption	2,6 tonne water/tonne cloth 1.85 JOD/tonne	12 months 1.68 tonnes/day	3,000 JOD Around 600 tonnes/year
Chemical Consumption	USD 277 / tonne cloth (197 JOD / tonne cloth)	12 months 1.68 tonnes/day	Around USD 169,856.4 / year (365 days operation /y) (120,800.4 JOD/year)
Operators (HR)	4,000 JOD/year	15 operators (5/shift), 12 months	60,000 JOD/year
Recycled Claim Standard (RCS) certification (*)	5,000 USD	1/year	5,000 USD (3,517.5 JOD)
Total OPEX for cellulose powder and PET granulates (first year)			234,548 JOD

(*) An international, voluntary standards that set requirements for third-party certification of recycled input

Simple Payback Periods

	Initial investment cost (JOD)	Annual operational costs (JOD/year)	Annual Benefits (JOD/year)	Simple Payback period
End Product of the new value chain				
Cellulose powder and PET granulates	1,347,000	234,548	463,298	~ 6 years

- This calculation is for a 1.68 tonnes/day capacity plant
- The payback period is calculated using the payback method, where initial investment is divided by positive cash flow produced per year. The depreciation isn't taken into consideration.

ENABLING FACTORS

- There is no clear demand for yarn production in HIE as there are very few knitting factories in the estate.
- Further vertical integration of the larger producers in HIE by taking up spinning and weaving fabrics can make added value out of chemical recycling products like PET, resin chips and cellulosic pulp for the spinning of new fibres.
- There are impact investment funds which may provide financial support in the form of loans and quasi-equity investments (e.g. Amam Ventures).
- EBRD's new green financing facility may provide financial and technical support for the implementation of this business case.

IMPLEMENTATION ROADMAP

SHORT-TERM (1 YEAR)	KPI	Timeline	Cost Incurred
Assess feasibility of recycling hub	Feasibility assessment completed	Y1 Q1	Yes
Identify potential investors for the required capital investment	Potential investors identified	Y1 Q1	No
Allocate and acquire funding	Commitments from investors/financiers	Y1 Q3	No
Initiate collaboration among factories in the cluster	Collaboration among factories initiated	Y1 Q4	No

MID-TERM (2-3 YEARS)	KPI	Timeline	Cost Incurred
Provide technical training for the operation of the hub	Operators training completed	Y2 Q1	Yes Around 10,000 USD
Establish textile waste sorting and separation operation	Textile waste sorting and separation established and operational	Y2 Q1 – Y3 Q4	Yes
Establish the recycling hub	Chemical recycling hub established and operational	Y2 Q2 – Y3 Q4	Yes (Around 1,5 Mio USD)
Start recycling hub operations	Monitoring mechanism operational	Y2 Q2 – Q3	Yes -around 290,000 USD operational costs /y
Develop a marketing strategy of the success story	A marketing strategy of a successful operation is in place	Y3 Q3 – Q4	No

LONG-TERM (5 YEARS)	KPI	Timeline	Cost Incurred
Increase visibility of the recycling hub	Activities to increase the visibility of the chemical recycling hub, a marketing strategy is implemented	Y5 Q1	No
Implement a marketing strategy		Y5 Q1	Yes

CONCLUSION

Business Case 4 suggests the establishment of a joint recycling hub which employs chemical recycling processes such hydrothermal separation (e.g. The Green Machine). The chemical recycling converts the textile waste into yarn which can be used by knitting factories within HIE. The implementation of this business case may be limited by the availability of investments. Chemical recycling doesn´t yet exist at a commercial scale. Additionally, it will impose environmental risks especially in terms of energy and water consumption (with water consumption being a significant limiting factor considering that Jordan is a water scarce country). The operation of the recycling hub would also impose an adequate wastewater treatment and eventually a regeneration or/and incineration option for the loaded activated carbon which is used in the decolouring process.

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