A Feasibility Study on a Fabric Waste Recycling Pilot Unit in Cambodia

FABRIC Cambodia

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អាល្លឺម៉ង់
DEUTSCHE ZUSAMMENARBEIT

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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List of Abbreviations

Abbreviation	Full Form
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CMI	Chip Mong Insee
COGS	Cost of Goods Sold
DCF	Discounted Cash Flow
DG Set	Diesel Generator Set
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
Export QIP	Export Qualified Investment Project
FCF	Free Cash Flow
FWRP	Fabric Waste Recycling Pilot
GDT	General Department of Taxation
GHG	Greenhouse Gases
HKRITA	The Hong Kong Research Institute of Textiles and Apparel
IRR	Internal Rate of Return
ISO	International Organization for Standardization
IT	Information Technology
kWh	Kilo Watt hour
MISTI	Ministry of Industry, Science, Technology & Innovation
MLVT	Ministry of Labour and Vocational training
MoC	Ministry of Commerce
MoE	Ministry of Environment
MoU	Memorandum of Understanding
NPV	Net Present Value
OPEX	Operating Expenses
PAT	Profit After Tax
PBT	Profit Before Tax
PC	Polyester Cotton
PLC	Programmable Logic Controller
PToI	Prepaid Tax on Income
PwCPL	PricewaterhouseCoopers Private Limited
QIP	Qualified Investment Project

RCC	Reinforced Cement Concrete
rPET	Recycled Polyethylene Terephthalate
SAM	Standard Allowed Minutes
SAP	Super Absorbent Polymer
SEZ	Special Economic Zone
SGA	Selling, General and Administrative Expenses
SMEs	Small and medium Enterprises
TEV	Techno-Economic Viability
ToI	Tax on Income
USP	Unique Selling Point
UV	Ultraviolet
VAT	Value Added Tax
WACC	Weighted average cost of capital
WC	Working Capital
WHT	Withholding Tax
WIP	Work in Progress

1. Project background

The fashion industry is most probably one of the largest polluters and highest resource intensive industries in the world. With increasing disposable income, and abundant availability of cheap clothing, per capita consumption and subsequent discarding of garments has reached an alarming level. Following statistics have been taken from a report from the 'World Economic Forum':

- The fashion industry produces 10% of all global carbon emissions and is the second-largest consumer of the world's water supply.
- 85% of all textiles end-up in landfills each year. The equivalent of one garbage truck full of clothes is burned or dumped in a landfill every second.
- 500,000 tons of microfibers is released into the ocean each year; the equivalent of 50 billion plastic bottles. Many of those fibers are polyester, a plastic found in an estimated 60% of garments.

The global manufacturing industry, governments and associations have recognized this environmental damage and have undertaken multiple initiatives to mitigate the impact. One such step is the introduction of recycling technologies that are developed with the aim of closing the loop on textile and apparel manufacturing by utilizing the waste generated (pre- and post-consumer) to re-create new textiles through mechanical and chemical processing of waste.

However, these technologies have not been able to reach the required scale due to multiple challenges including the inherent complexity of textile and apparel operations (collection and sorting of waste) and commodities (significant use of blended fibre-based products), the largely unorganized nature of the manufacturing industry (lack of interest amongst stakeholders), high costs (lack of economic viability in current solutions including using large amount of labour to manually sort and segregate waste and procuring technology to process waste), etc.

The Hong Kong Research Institute of Textiles and Apparel (HKRITA) has developed a technology (Green Machine) which uses a Hydrothermal Separation System to regenerate polyester fibre from blended textile waste. HKRITA has already initiated a pilot plant in Indonesia (Kahatex facility).

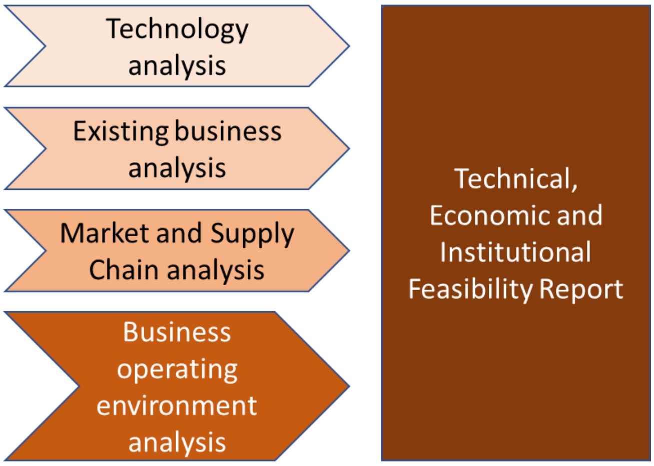
GiZ under its program FABRIC[1] has tied up with a group of stakeholders including HKRITA, H&M Foundation, VF Corporation, Dakota, and Chip Mong Insee and subsequently commissioned a ***feasibility study of a post-industrial Fabric Waste Recycling Pilot Unit (FWRP) in Cambodia.*** If the Techno economic viability (TEV) study of this project in Cambodia is successful it may then get replicated in other major textile manufacturing countries and may bring in a significant positive impact in circularity.

PricewaterhouseCoopers Private Limited (PwCPL India) was assigned to conduct the feasibility study. The overall project timeline was of 18 weeks starting from 10th March 2022 (the date of kick-off meeting).

[1] Fostering and Advancing Sustainable Business and Responsible Industrial Practices in the Clothing Industry in Asia

2. Methodology adopted

We have used the following four steps approach i.e., technology analysis, existing business analysis, market analysis and business operating environment analysis to carry out this study. The work steps will be undertaken in a parallel manner to develop the technical, economic, and institutional feasibility report.



Project initiation/Kick-off meeting: GiZ FABRIC team had set up the introductory/kick-off meeting with all the internal stakeholders and PwC on 10th March 20222. The agenda of this meeting was to formally introduce the feasibility study team from PwC to the MoU signatories. The importance of this project, the roles, and responsibilities of each of the internal stakeholder were re-iterated in this meeting. It was decided that PwC will set up one to one introductory meeting with all internal stakeholders to collect more details of the project.

Literature Review and One-to-one Interviews with Internal Stakeholders: After the kick-off meeting, GiZ FABRIC team provided the PwC team with some of the relevant documents. PwC team went through those documents carefully and highlighted the major takeaways from it in the inception report. The team also studied about the project stakeholders in detail including their contribution towards the project and developed specific discussion points for the online interviews to obtain the most relevant insights.

As per the agreed action points, the project team carried out multiple consultations with the project stakeholders. The project team collected more reports, technical datasheets, machine drawings and other relevant documents from stakeholders including MoU signatories.

Detailed study and analysis of those documents was carried out to develop a deeper understanding of the work done so far; role, responsibilities, and interests of different stakeholders; the potential of the envisaged Fabric Waste Recycling Pilot Unit (FWRP) and expectations from this project.

Technology analysis: The project team (from PwC India and Indonesia) visited the Green Machine facility in Indonesia and discussed with the management team and HKRITA onsite engineers. We understood the technical details of the machines, installation process and requirements, raw material and other input materials (e.g. chemicals) requirements, quality specifications, source, availability, cost of procurement and price fluctuation; energy and water requirements; skilled manpower requirement and availability; operational cost; challenges faced in operating the machine/plant and the risk mitigation measures; safety precautions followed; maintenance schedule; spare parts requirements and availability; organization structure; the market potential of end products; marketing channels used; institutional tie-ups required; best practices followed; pricing of the products and its sensitivity to input material cost.

Market and supply chain analysis: We had multiple detailed discussion with VF Corporation representatives and its supply chain partners on the recycled polyester fiber developed by FWRP to understand its potential use; potential demand in the coming 5 years; headwinds and tailwinds for demand; expected price range, its potential growth/degrowth with time and sensitivity to other business factors; alternative / competing materials, its demand and supply gap; and competitive advantages. Priorities of the brand regarding this project, critical requirements (technical, commercial, and business) of its supply chain and other compliance issues (e.g., traceability, social sustainability) were also discussed with the VF Corporation.

Discussions with Dakota Manufacturing were carried out for understanding the challenges associated with the sourcing of fabric waste, the quantity of waste available for each type of quality, factory production routine, fabric purchase, sustainable material market and prices. Overall project concept, supply chain, demand pattern and specific requirements (technical, commercial, and business) of the buyers were also discussed.

Business operating environment analysis: Project team interacted with Government departments (MISTI) and service providers (Chip Mong Insee), and subject matter experts in Cambodia to understand the cost of construction, installation, operation and maintenance of FWRP; transportation costs; availability of required skill sets; present taxation systems on the fabric waste; other Government taxes/duties related to import / export of materials and running of the business; relevant laws, regulations and compliances for setting up and running the FWRP in Cambodia; potential locations and its competitive advantages.

Technical, economic, and institutional feasibility report preparation: Input received from technology analysis, present business analysis, market and supply chain analysis and business operating environment analysis were collated and analyzed further to provide cost estimates, financial analysis, project impact, possible alternative locations, possible alternative evaluations, need analysis/marketing aspects, process work, timeline, conclusions, and recommendations of the proposed project (an FWRP using Hydrothermal Separation System) in Cambodia.

The project team first analyzed whether the anticipated demand-supply gap is sufficient to justify setting up an FWRP facility in Cambodia.

The optimal size of the planned FWRP facility was then determined based on the technical and economic insights received through desk research and primary research. Overall land requirement, broad investment requirements, requirements of critical input materials and skill set requirements were discussed and agreed upon with the GIZ FABRIC team and other relevant stakeholders.

The location of the plant was identified through a detailed analysis. Technical feasibility including the availability of energy, water, other input materials and human resources; the cost-effectiveness of the business; connectivity with major markets and ports and regulatory and compliance requirements of three potential locations within Cambodia were analyzed.

Pricing of the end products of Green Machine was determined based on the manufacturing cost, expectations of the potential buyers and price of alternative materials. A comparative table highlighting the quality test results has been developed between the virgin materials and the final outputs of the Green Machine.

Detailed human resource requirement, its total cost to the company, roles and responsibilities for the key positions have been provided in this report. Training requirements and facilities have also been outlined for the machine operator.

The financial and economic feasibility analysis covers CAPEX and OPEX analysis, revenue and profit estimation, analysis of other key financial ratios (payback, IRR, NPVs) and sensitivity analysis of the key success factors. It is used to determine the potential sustainability of the business and its attractiveness in long run.

An appropriate institutional setup has been proposed for the successful implementation and sustained operation of the project. The project team has explored and suggested the role of Government departments, and private players, governance mechanism and required capacity developments. A formal procedure for factories to register their fabric waste selling and required related changes in Government policies have been proposed.

Business and operational risks have been identified, and corresponding mitigation measures have been proposed. This draft feasibility report was discussed with the GIZ FABRIC team and MoU participants. Feedbacks and recommendations received in this discussion were appropriately incorporated in the final version of the report, executive summary and PPT presentation.

3. Stakeholder coverage

During this project, we had several discussions with both the project and external stakeholders. The table below highlights the name of the stakeholders and relevant areas of discussions:

Table 1 Stakeholder Coverage

<table>
<tr><th>Areas covered</th><th>Stakeholders covered</th></tr>
<tr><td rowspan="12">
Green machine operations
Capital expenditure - Green machine and miscellaneous fixed assets (HKRITA)
Operational cost parameters
Market for recycled polyester fibre and competition from PET bottle recycled fibres
Availability of raw material for green machine operations in Cambodia
Key locations for setting up the pilot plant in Cambodia
Government’s support to recycling facilities in Cambodia, regulatory requirements, status of ‘Centralized recycling facility
Alternative application areas of Green machine fibre and corresponding prices of competing material
Comparison of properties of yarn and fabric made from rPET (Green machine) vis-à-vis virgin polyester and recycled polyester (PET bottle)
</td><td>HKRITA</td></tr>
<tr><td>Kahatex</td></tr>
<tr><td>VF Corp</td></tr>
<tr><td>Dakota</td></tr>
<tr><td>Chip Mong Insee</td></tr>
<tr><td>Shingkong</td></tr>
<tr><td>Cosco</td></tr>
<tr><td>Ministry of Industry, Science, Technology, and Innovation (MISTI), Government of Cambodia</td></tr>
<tr><td>Ministry of Environment (MoE), Government of Cambodia</td></tr>
<tr><td>Multiple non-woven manufacturers in India</td></tr>
<tr><td>Recycled polyester yarn traders in India</td></tr>
<tr><td>Bluwin Limited - Chemical experts</td></tr>
</table>

The stakeholder coverage was done using a combination of virtual and physical meetings. The stakeholders shared vital information and supporting documents such as test reports, costing information, samples, etc. that provided key inputs in the development of this report.

4. Technical analysis

a) Product

i. Raw material

Fabric waste: The ideal feed material for the green machine is a woven/ knitted / non-woven, fabric of polyester cotton blend. This feed perfectly aligns with the objective of the Green machine, i.e. achieving complete circularity. In case of polyester blend with other natural fibre such as wool, silk, etc., the natural fibre will get completely dissolved in the acidic solution used in the process.

Input fabric limitations:

- If the feed material, i.e. fabric waste, contains more than 3% of nylon / spandex, it may result in the clogging of the machine pipes and machine may need to be stopped for cleaning.
- Coated & laminated fabrics and quilts are not suitable as feed material for this machine.
- Dope dyed fabrics are also not suitable to be processed in the de-coloring machine.

The required fabric waste is generated either at the pre-consumer stage (generated in the manufacturing process) or at the post-consumer stage (generated at the consumption stage). The post-consumer (i.e. worn or used textile articles) waste requires additional processing (e.g. mechanical cutting, removal of metal parts, labels etc.) before feeding into the Green Machine while the pre-consumer waste generally require only cutting into smaller pieces before feeding. The pre-consumer fabric wastes can be obtained from multiple sources as indicated in the table below:

Table 2 Source of pre consumer waste

Garmenting factory	Weaving/ knitting/ non-woven mill
Cut and sew fabric scrap (>95% share)	Fabric weaving waste
Defective or otherwise unsold garments	End-of-roll textile waste
Clothing sample waste	Fabric processing waste/rejects
Textile swatch waste	Sampling yardage waste

Source: Primary and secondary research

~10 cm X ~10 cm fabric pieces are ideal as the feed material. Non-uniform size feedstock (Figure 1) needs to be converted into a compatible size (Figure 2) for efficient processing in the machine. Too short or long a fabric piece may impact the output fiber length and efficient machine operation.

Figure 1 Fabric waste feedstock of non-uniform size

Figure 2 Fabric waste cut into ~10 cm X ~10 cm

Source: Pilot facility in Indonesia

Acid: The hydrothermal process of the Green Machine uses a biodegradable chemical i.e., Organic acid as an input to the process. 90% of this acid is recoverable from the process.

Absorbent: The de-coloring process of the Green Machine uses absorbent as a medium to absorb the dyes from recycled polyester fiber surface. The materials cannot be recovered post the process and can be incinerated.

ii. Finished product

Fabric waste passes through two separate processes within the Green Machine i.e. i) Hydrothermal separation and ii) Decoloring process. Details of these processes are given in the next chapter. Strands of de-colored polyester fibers of varying length and ~98% purity is the primary output of these two processes.

Figure 3 Output of Hydrothermal separation

Figure 4 Output of De-coloring process

Source: Pilot facility in Indonesia

These strands of fibers can't be directly used in conventional short-staple spinning system. The following process can be adopted to make the recycled Polyester fibers suitable for spinning:

The output of Green machine (Figure 5) is passed through a standard mechanical shredding machine which converts the strands into a fibrous material. This material is then passed through a blower to achieve fiber individualization. Fibers of this stage is suitable for short staple spinning processes. These fibers are then pressed into a bale form for ease of transportation.

Figure 5 Green machine output

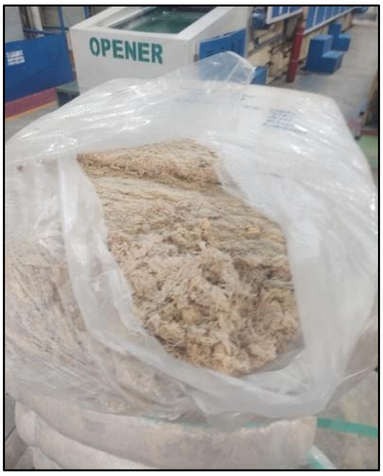


*Figure 6 Output of shredding process**

Source: Pilot facility in Indonesia

(*Please note that the fibers shown have taken been directly from the hydrothermal output and thus contains color[2])

Further, to further understand the technical viability of the recycled polyester fibers coming out from Green machine (rPET), a comparative assessment of the quality of this fibre and its value added products i.e. yarn and fabric has been done against virgin PET and conventional blended materials.

[2] This study considers sale of de-coloured fibre. However, even mechanically processed colored fibre (output of only the hydrothermal process) may also be sold in the suitable markets.

Comparative analysis of quality of fibre

The **Table 3** highlights the molecular weights (Mn and Mw) of virgin PET and rPET fibre (after hydrothermal separation process). The results indicate that molecular weights of the PET fibres were not affected by the hydrothermal treatment i.e. PET did not depolymerize after hydrothermal separation process.

Table 3 Comparative assessment of molecular weight of virgin PET against rPET

Parameters (grams/mole)	PET 100%	Recycled fibres (52 Polyester /48 Cotton)
Mn (the number average molecular weight)	12,109	13,201
Mw (the weight average molecular weight)	37,325	36,334

Source: HKRITA

Comparative analysis of quality of yarn and fabric made of recycled polyester fiber of Green machine:

A quality comparison of spun yarn and fabric manufactured using rPET and conventional virgin polyester was carried out. Following product compositions were used to carry out the comparative assessment:

Table 4 Product composition for comparative assessment of quality

Type	Green machine output	Conventional product
Spun Yarn (32s)	**Composition A -** 100% rPET	**Composition A' -** 100% Virgin PET
	Composition B - 50% rPET / 50% virgin PET	
	Composition C - 60% cotton / 20% rPET/ 20% virgin PET	**Composition B' -** 60% cotton / 40% virgin PET
Fabric	Fabric made from the Composition A and A' have been taken for fabric quality comparisons	

Source: Pilot facility in Indonesia

Yarn quality comparison: The comparative assessment of the yarn varieties is shown in **Table 5**:

Table 5 Comparative assessment of yarn quality

Yarn quality parameters	Focus quality		For comparison	Focus quality	For comparison
Fiber composition of yarn (32s Ne)	**Composition A**	**Composition B**	**Composition A'**	**Composition C**	**Composition B'**
Tenacity (g/tex)	460	530	580	290	312
Breaking elongation (%)	12.3	12.6	13	6.3	6.2
Hairiness index (H)	3.6	3.5	3.4	5.05	4.8
Unevenness (%)	10.2	9.6	9	11.3	10.9
CV (%)	12.75	12	11.25	14.12	13.63
Normal imperfections/km					
Thin places (-50%)	3	2	1	5	3
Thick places (+50%)	21	16	12	58	42
Neps (+200%)	38	32	25	205	167
Total imperfections (No.)	61	50	38	268	212
Twist Multiplier (TM)	3.47	3.37	3.28	3.67	3.51

Source: Pilot facility in Indonesia

From the above comparison, it may be inferred that focus quality yarns have lower tenacity and higher imperfections compared to conventional products. The difference is higher in case of 100% rPET yarn. **It might be advisable to use rPET as a blend with other fibers**.

Fabric quality comparison: The comparative assessment of the fabric varieties is shown in **Table 6:**

Table 6 Comparative assessment of fabric quality

Fabric quality parameters	Focus quality	For comparison	For comparison
Fabric composition	**100% rPET**	**100% Virgin PET**	**Fabric made of 60% cotton 40% virgin PET**
Grey Fabric			
Shrinkage	-0.3 to +0.2	<2	<2
Bursting strength (kg/cm^2)	152.4 kPa	>=130 kPa	>=170kPa
Pilling (rating)	4-5	>=3	4-5
Finished Fabric			
Colour fastness to rubbing	4-5	4-5	4-5
Colour fastness to washing	4-5	4-5	4-5
Colour fastness to perspiration	4-5	4-5	4-5
Colour fastness to light	3+	3+	3+

Source: Pilot facility in Indonesia

From the above comparison, it may be inferred that **fabrics made from 100% rPET have comparable quality results on different testing parameters against conventional fabrics.**

Cellulosic powder: The cotton component of the polyester-cotton blended fabric waste gets converted into cellulosic powder (shown in Figure 7)

Figure 7 Dry Cellulosic Powder

Source: Pilot facility in Indonesia

b) Green Machine operation

The Green machine comprises of two separate processes i.e. Hydrothermal separation and De-coloring. The hydrothermal process separates polyester fiber from cotton and the de-coloring process absorb the dyes from the recycled polyester fibers coming out from the hydrothermal process.

The subsequent segments will provide details on the entire Green machine operations starting from the (a) preparatory process, (b1) Hydrothermal process, (b2) Cellulosic powder drying, (c) De-coloring and (d) Hydro extraction and drying.

Figure 8 Process flow of Green machine operation

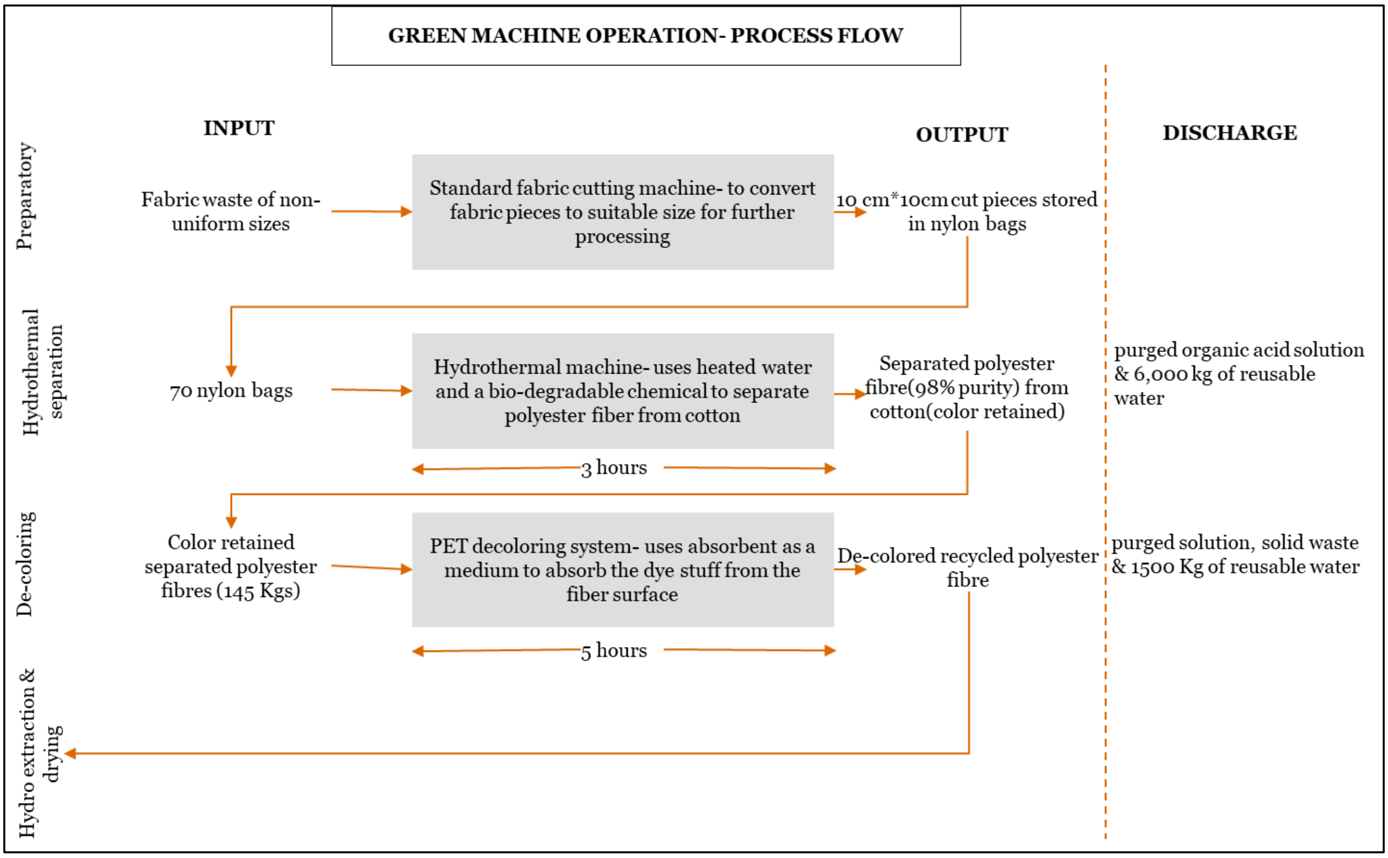


Table 7 highlights the quantum of feed materials required for the first batch and the subsequent batches. In the first batch higher quantum of organic acid and water are used to prepare the bath suitable for hydrothermal process.

Table 7 Inputs required for hydrothermal separation process

Input requirement	Quantum of feed/batch (kg)	
	First batch	Subsequent batch
Blended fabric waste	210	210
Organic acid	489	49
Process water	2,488	249
Rinsing water (can be reused)	6,000	6,000

Source: HKRITA

The total energy consumption for a 3 hour batch (excluding the first batch) stand at 505 kWh.

The resultant recycled polyester fiber has ~98% purity levels. The process generates non-hazardous effluent in the form of purged organic acid solution. 6,000 kg of water is used for rinsing purpose which can be reused in subsequent processes.

Table 8 highlights the quantum of input required for a single batch of decoloring process. The total energy consumption for a 5 hour batch (excluding the first batch) stand at 607 kWh.

Table 8 Inputs required for de-coloring process

Input requirement	Quantum of feed/batch (kg)	
	First batch	Subsequent batch
Recycled polyester – feed stock	145	145
Absorbent	200	7.41
Process water	2,000	200
Rinsing water (can be reused)	1,500	1,500
Anti-back staining agent	120	12

The photos shown in **Figure 9** showcase the impact of the decolorization on dyed fabric waste feed.

Figure 9 Results of the de-coloring process

One sample of rPET fibers coming out from the de-coloring process was tested by HKRITA for the residual chemical content and those were found to be conforming with buyer's requirements. The process generates non-hazardous effluent in the form of purged solution and solid waste. 1,500 kg of water is used for rinsing purpose and this water can be reused in subsequent processes.

c) Land and building requirements

The total built up area required for one set of Green Machine with an input capacity of 1.5 ton per day is ~980 sq. mtr. This area includes space for raw material and finished goods storage area, space for fabric cutter machine, and other administrative and ancillary spaces. The table below highlights the area requirements for the machine, auxiliary equipment, buildings etc.:

Table 9 Area specifications of the Green Machine

Machinery/ Equipment	Area (Sq. mtr)
Hydrothermal separation system (including the cellulosic powder drying system)	200
rPET De-coloring system (including the hydroextractor and dryer system)	200
Raw material (waste fabric, chemical and absorbent) and finished good storage	60
Fabric cutter	~60
Fibre shredding machine system	130
Open space	330
Total built-up area	**980**

Source: HKRITA

The machine can be housed in either a single-storey or multi-storey building preferably built using RCC construction. If the machine is being set-up in a standalone building, following basic industrial requirements need to be met:

- Power and water connection
- Connecting road
- Sewage
- Admin building

The total land area requirement will depend on the location as the ground coverage needs to meet the local government regulation of Government of Cambodia.

d) Machine installation and trial run requirement

The machine needs to be imported. It will take ~6 months from the order date to get it delivered to Cambodia.

A team of 4-5 people, including an engineer from HKRITA, 1 technician, 1 welder, 1 electrician and helpers, will be required for the installation and initial trial of the machine. A total of 40-50 man-days, ranging over a period of 1-2 months, will be needed for the machine installation.

5. Human resources requirements

The hydrothermal separation and decoloring system of the Green machine is not manpower intensive in nature. Process-wise breakup of manpower requirement along with the basic roles and responsibility is provided in **Table 10:**

Table 10 Human resource requirement for one set of Green Machine

Process	No. of operators required / batch	Roles & Responsibility
Hydrothermal operation	3	• Arranging fabric waste for preparatory section • Operating the fabric cutter • Placing the cut fabric pieces in nylon laundry bags • Operating the hydrothermal machine • Collecting the liquid cellulosic output into buckets • Operating the cellulosic powder dryer
De-coloring operation	2	• Feeding the output of hydrothermal separation into the de-coloring machine • Operating the de-coloring machine • Operating the extractor and dryer • Storage of finished goods
Mechanical Shredding	4	• Handling the output of de-coloring operations • Operating the shredding, blower and bale press • Handling the storage of final bales
Supervision and management	2-3	• Supervising the entire operation

Source: HKRITA

Skill set requirement: The operator must have a good understanding of the textile operations primarily washing and dyeing processes. It is preferred that the operator has good trouble-shooting skills and can understand English to study and refer to the operating manual.

Training: The training for the Green machine requires a total of 6 working days; 3 days each for the hydrothermal and PET decolorizing machine. The training is conducted on-site by HKRITA officials and covers detailed instructions on the PLC system operation and trial runs of both hydrothermal and decoloring machine.

6. Capex and Opex analysis

a) Green machinery and other fixed assets cost

The Green machine comprises of sophisticated processes involving multiple high-performance equipment.

The total capital expenditure of the Green machine developed by HKRITA and installed at the Indonesian facility is **~US$ 2.0 mn.** The **Table 11** provides a detailed break-up of the cost of different components of the Green machine:

Table 11 Capital expenditure on the Hydrothermal separation and decoloring system

Particulars	No. of Units	Amount (USD)
Hydrothermal		
Processing Vessel Machine - 135°C	2	375,000
Loading Conveyor	1	24,500
Hydro Extractor	1	128,000
Drying Machine - 150 kgs	1	53,000
Vacuum Dryer	1	21,000
Rotary Drum Screen	1	19,000
Basket Filter	4	
Filter Gasket	4	
Scrapper Self Auto Clean Filter	2	53,000
Filter Elements for the Scraper Filters	2	
De-coloring system		
De-coloring Machine - 180°C	2	515,000
Absorbent Filters	2	27,000
Total cost		**1,215,500**

Source: HKRITA and Indonesia facility

Table 12 Total expenditure on installing one set of Green machine

Particulars	Amount (USD)
Green machine	1,215,500
Fabric cutter	~3,000
Mechanical fibre shredding machine	~40,000
DG Set (800 kW)[3]	~45,000
Compressor (20 kW) – used for actuators[3]	~10,000
Electrical panels and fittings[3]	~7,000
Piping and other auxiliary equipment[3]	~12,000
Project Management & Engineering	403,500
Travelling for machine installation	31,000
License Fee	235,130
Grand Total	**~2,002,130**

Source: HKRITA, PwC analysis, and secondary research

b) Operational expenditure

The Green machine has been developed as a resource efficient machine. The resources (i.e. energy, chemical, water, charcoal, etc.) requirements reduce significantly from the first batch to the subsequent batches as majority of the resources can be re-used in the operations with small modifications. It also helps in reducing the operational expenditure.

The operational expenditure (cost per batch) break-up for running both the Hydrothermal and De-coloring machine is provided in **Table 13.** The standard operational expenditure for running the Green machine is **USD 1.13/kg.**

[3] Based on internal analysis of the estimated requirement of power

Table 13 Operational expenditure breakup for running the Green machine

Parameters (USD)	First Batch		Subsequent Batches	
Chemical cost	244	340	24	28
Energy cost	61	66	45	55
Labour cost	18	20	18	20
Water cost	1	0.35	1	0.17
Total cost	325	427	89	103
Total cost per kg of input Hydrothermal – 210 kg input De-coloring – 145 kg input	1.55	2.94	0.42	0.71
	USD 4.49/kg		USD 1.13/kg	

Source: HKRITA

7. Market analysis

a) Raw material – Fabric waste

Garment manufacturing is one of the leading industries in Cambodia. The industry exported USD 12.3 billion worth of garments in 2020 representing ~47% of the total merchandize exports of the country. Between 2010 and 2020, the garment exports from Cambodia grew at a healthy pace of 11% CAGR. Garment industry is a major source of industrial waste in the country. As per the data obtained from the Ministry of Environment, 60% of all industrial waste in landfill comes from the garment industry, equating to around 90,000 tonnes in 2019. With the growth of Cambodia's garment exports, the waste generation will also keep on increasing.

Government of Cambodia has brought in several measures to regulate the waste disposal processes of the country. However, despite these efforts, a large part of the fabric waste collection and disposal is still unorganized in nature. Some large and medium sized garment manufacturers are using the service of licensed waste collectors and this number is growing every year.

Organized waste collection and disposal: As per Ministry of Commerce of Cambodia, there were 625 registered garment factories in Cambodia at the end of 2018[4]. Out of these, more than 100 factories (primarily large factories) practice organized waste collection and disposal processes.

Depending upon the design of the garment and marker efficiency, a factory usually generates 2-20% of fabric waste. Majority of the waste (~98%) is generated at the cutting stage while some waste also comprises of left over fabric rolls. Under the organized sector, generally a contract is signed between the garment factory and the waste collection and disposal company for the sale and purchase of fabric waste. It involves paying annual lump-sum to the collector for its services which ranges around USD 7,000-10,000 for large factories. The waste so collected from this process is disposed using i) burning ii) using as an input in manufacturing of cement clink and iii) dumping in registered landfills.

Dakota, which a vertically integrated garment manufacturer, has a contract with Chip Mong Insee (CMI) wherein CMI charges USD 160 per 12 tonne truck of waste. Dakota's waste generation from their factories in Cambodia stand at 20 tons per month i.e. 2 truckloads.

CMI is one of the few licensed waste collectors and recyclers in Cambodia. CMI is a cement manufacturing company. CMI has a structured collection process that includes sampling of waste, training of garment factory officials in waste sorting at source (hazardous and non-hazardous), etc. CMI is working primarily with a significant number of brands nominated factories. However, over the last few years, some large factories have voluntarily contracted with CMI to adopt the formal waste disposal process. CMI uses the garment waste in its cement manufacturing process which results in net zero waste disposal.

Unorganized waste collection and disposal: The unorganized sector represents ~85% of the waste fabric collection and disposal[5]. The common disposal techniques are illegal dumping in landfills, burning in incineration boilers as a cost recovery method, use in alternate applications such as cleaning cloth, hammocks, floor mats, stove fuel, and exports, primarily to China. However, exports of waste have become increasingly difficult as China (and subsequently other countries) has implemented a series of waste management reforms over recent years which included the ban on import of textile waste in 2017. By the end of 2020, import of all waste to China had been banned.[6]

There is sufficient availability of pre-consumer fabric waste which can be used as feed material for the Green Machine Pilot Unit in Cambodia

[4] https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/publication/wcms_714915.pdf
[5] Discussion with Chip Mong Insee
[6] Waste Streams Mapping Report by GiZ

b) Output - Recycled Polyester Fiber

In last five years, the global fashion industry has been setting ambitious targets for itself related to environmental sustainability. A significant portion of these targets are related to use of sustainable raw materials, using reused / recycled fibers, reducing landfill, developing circular business model etc. The Figure 10 highlights select targets set by some of the major global apparel brands.

Figure 10 Selected sustainability targets of a few international brands

Brand	Target	Year
VF Corp.	Half of polyester will come from recycled materials	2025
Inditex	Achieving Zero Waste to landfills from any of the own facilities	2023
	Use of 100% sustainable cellulosic fibers	2023
	Use of 100% recycled polyester	2025
M&S	100% conversion to preferred fibres by 2025 for Polyester and Man-made cellulosic fibres (viscose, modal, lyocell)	2025
	Make 25% of M&S Clothing & Home products using at least 25% reused or recycled material	
	Becoming a circular business generating zero waste and facilitating the collection of at least three million garments a year for reuse and recycling	
GAP	Make 50% of products with sustainable fibers - Banana Republic	2023
	Make 80% of materials with sustainable fibers – Athleta	2020
	Divert 80% of store waste from landfill - Athleta	2020

Source: Secondary research

Polyester, which has highest share (~52%[7]) in global fiber consumption, is one of the major target fibers for achieving the sustainability targets mentioned above. Brands and their supply chain partners have reported an exponential increase in use of recycled polyester in their product portfolio over the last few years.

A 10-15% y.o.y increase in demand of sustainable fibres – *COSMO Fabric*

Recycled polyester comprises 40% share of total filament consumption – *Shinkong Textiles*

Recycled polyester comprises 81% of total fibre sourcing — *The North Face*

~5 Mn tons of recycled polyester fibers, which is 14% of the total polyester fiber consumption, were consumed in 2019 and this figure is growing at a healthy rate.

A joint initiative undertaken by the *Textile Exchange and the United Nations Framework Convention on Climate Change's Fashion Industry Charter for Climate Action* has put forth a challenge to the fashion industry to increase the share of recycled polyester fiber consumption within total polyester fiber consumption from 14% to 45% by 2025[8]. More than 70 global fashion brands have signed up for this challenge. This translates to a potential **market addition of ~10 million tons in the next 3 years.**

This growing demand of recycled polyester is currently being met mainly by mechanical recycling of PET bottles (major source) and mechanical recycling of pre and post-consumer polyester textile waste. But these technologies have some inherent challenges which have been mentioned in the below:

- Due to the degradation of polymers and contamination that occurs over multiple use cycles, mechanical recycling eventually degrades the value of the PET and often prevents it from recirculating into higher value applications such as fiber-to-fiber recycling.

[7] Share in global fibre consumption – Fiber Year 2019
[8] Textile Exchange

- Large variations in construction, colors, finishes and shapes of both pre and post-consumer textiles makes it difficult to sort textiles for mechanical recycling

Meanwhile, Green Machine technology can overcome some of these challenges. It has the ability to process blended and multiple colored fabrics without causing much degradation to the quality of the original raw material.

For Green Machine technology to scale up and occupy higher share in the recycled polyester fiber market, the major focus must be on reduction of prices and identifying the right end use category. Currently the recycled polyester (from PET bottles) prices are comparable to the virgin material. It is estimated that usage of rPET (Green machine output) will increase garment cost by 10% - 15% compared to garments manufactured using virgin Polyester fiber.

c) Byproduct - Cellulosic Powder

The cellulosic powder generated as a byproduct of the Green machine is hydrophilic in nature and has the potential to be used in multiple areas. Chemical and mechanical processing of this cellulosic powder is required to make it suitable for different applications. A list of potential application areas of treated cellulosic powder is mentioned below:

1. **Super Absorbent Polymer (SAP):**

a. SAPs are hydrophilic networks of polymers that have the capacity to absorb and store a lot of water. They are developed after dissolution, crosslinking, drying, milling, and sieving of cellulose powder recovered after hydrothermal separation of Polyester Cotton fabric. SAP made from cellulosic powder has high liquid retention (26.6 g saline solution/ g material) and absorption capacity (31.4 g saline solution material). Thus, they can be used in agricultural / irrigation purpose, especially in the cultivation of cotton[9].

Ongoing trials by HKRITA: Using SAP as a biodegradable, water retaining aid for cotton plantation. Preliminary experiment shows higher growth rate and yield by ~15% for cotton plant with SAP applied without additional irrigation

b. SAPs made from cellulosic powder are pesticide free, herbicide free and does not support microbial growth as it is purified, mechanically processed cellulosic powder. Hence, it is also used in pest management.[10]

2. **Pharmaceutical products[11]:[12]** Since cellulose is chemically inert in powder form, the human body does not digest it and it has no functional caloric value. Because of this property, it can be used as an alternate to lactose when formulating medicines for lactose-intolerant patients. It can also be used as a filler for making medicinal tablets with low friability owing to its desired binding properties and structure.
3. **Dietary products[10]:** Cellulose powder also find its applications in the food industry as it is neutral in taste / odour and chemically inert. It doesn't affect the colour or sensory properties of the food. Hence, it is processed and used as a dietary fiber and as an additive with multiple functions.
4. **Textiles industry:** The cellulosic powder can be converted into regenerated composite cellulose fiber after several mechanical treatments and chemical substitution reactions, which may then be used for manufacturing textile materials.

Ongoing trials by HKRITA: Development of functional regenerated fibers from recovered cellulose component from Hydrothermal Separation System, using a combination of nanocomposite techniques in wet spinning process. Mixing high density polymer cellulose (recycled/virgin viscose) with cellulose powder, adding nanocellulose as reinforcement to improve tenacity; ***trial is still in small scale; Trials with other additives will be conducted to provide extra performance for the yarn / fabric***

5. **Cosmetics[10]:** Powdered cellulose is utilized in formulating cosmetics and works as a thickening agent and adsorbent due to its texture and moisture control properties

[9] HKRITA
[10] Research paper - Superabsorbent polymers in agriculture and other applications: a review by Sabyasachi Behera & Prakash A. Mahanwa
[11] Please note that HKRITA has not conducted any trials for these applications.
[12] https://www.jrspharma.com/pharma-wAssets/docs/brochures/arbocel.pdf and https://www.jrspharma.com/pharma_en/products-services/excipients/fillers/functional-fillers-arbocel.php

8. Location analysis

The location of the proposed pilot facility will play a crucial role in determining the feasibility and long term sustainability of the unit. To carry out this analysis, multiple evaluation factors were identified based on which the potential locations were scrutinized. Those factors are as follows:

1. Proximity to raw material source
2. Proximity to buyer
3. Cost of manufacturing
4. Availability of resources

Based on our discussion with different stakeholders and our understanding of the geography of Cambodia, we have arrived at three potential locations for setting up the FWRP unit. The shortlisted locations are Phnom Penh, Kampot and Bavet. We have compared these three locations on the basis of above-mentioned four factors and its USP for understanding the degree of attractiveness for setting up a new FWRP unit:

Table 14 Location analysis matrix

Locations	USP	Proximity to RM	Proximity to Buyer	Cost of Manufacturing	Availability of resources
Phnom Penh	Largest hub of garment manufacturing	This location will offer a ready availability of different type of fabric waste in large volumes.	Inland water-ways and roads can be used for sending the rPET fiber to yarn manufacturers of Vietnam. Considerable logistics costs will be incurred.	The location has multiple SEZs (with considerable presence of garment factories). These SEZs offer fiscal incentives to factories. Cost of land/rental is comparatively higher than other proposed locations	Robust public infrastructure; good connectivity through roads, ports and airports; good supply of water, electricity and labour.
Kampot	Location of Chip Mong Insee's cement factory	This location also offers an already established stream of raw material supply i.e. use of garment waste in cement factory. However, sorting of the incoming waste will be a key challenge at this location.	Trade routes through Sihanoukville port and roads- can be used to trade the rPET fibre. Considerable logistics costs will be incurred. Although, a new port in Kampot is under construction that will likely reduce logistics cost.	Existing resources (such as boiler, generator, power connection, etc.) in the Chip Mong cement factory may be leveraged/shared to reduce manufacturing costs	Ready availability of land with Chip Mong and a robust public infrastructure in the area; good connectivity through roads, ports and airports; good supply of water, electricity and labour..
Bavet	Location at Cambodia-Vietnam Border	This location (although equidistant from Phnom Penh as compared to Kampot) does not have an established large scale supply of	This location offers the highest proximity and lowest logistic costs to the proposed consumption	The location has multiple SEZs. These SEZs offer fiscal incentives to factories. This	Robust public infrastructure; good connectivity through roads, ports and airports; good supply of water, electricity.

Locations	USP	Proximity to RM	Proximity to Buyer	Cost of Manufacturing	Availability of resources
		raw material for the proposed FWRP. Considerable logistic costs will be incurred in bringing the raw material to the factory location.	centre i.e. yarn manufacturing unit Vietnam.	location offers lower land rental costs.	However, the unit may face in sourcing of highly skilled labour.

The above analysis indicates that none of the location has significantly better advantages compared to the other locations. However, availability of properly sorted and labelled fabric waste will be vital for the success of the project. So, the FWRP unit may preferably be set up as part of an existing large apparel manufacturing unit which will improve its competitiveness from environmental sustainability / circularity point of view. The unit may also be set up as a stand-alone unit which is operated by a group of textile and apparel manufacturers which have their units in a particular apparel cluster.

9. Taxation analysis

a) Tax implications of fabric waste sales

The regulatory framework of the garment industry is quite complex in Cambodia, especially around the tax treatment of sales of fabric waste. Currently, most Cambodian garment manufacturers import fabrics from overseas. Cambodian garment manufacturers generally take the following steps for importing fabrics, manufacturing the garments and selling the fabric waste generated.

1. Import the fabrics with a clause that the developed garment will be exported so they get certain tax benefits.
2. The fabrics waste generated after manufacturing the garment must be disposed of using an authorised waste collection agent. This transaction is also considered as a local sale which has value-added tax (VAT), prepaid tax on income (PToI) and tax on income (ToI) implications.
3. For waste disposal, manufacturers must request permission from the General Department of Customs and Excise. The request must be attached with the import documents, annual tax submission proof to the GDT (where sale report and tax payment must follow general income tax policy) and other relevant documents.
4. The tax regulations don't specify a percentage of allowable fabric waste. Generally, the tax auditor would allow 5% of fabric waste during their tax audit on the cost of goods sold. According to the manufacturer, most of their total fabric waste exceeds the allowed levels (e.g. 5%).
5. The tax auditor compares the imported raw materials and exported finished goods by weight, which is shown on customs documentation. So, the taxpayers must justify the discrepancy. If the taxpayer can't justify the missing raw materials through the reconciliation, the tax auditor will deem the lost material as local sales of raw materials and apply 10% VAT, 1% PToI, and 20% ToI (after tax holidays).
6. If the fabric waste is sold to an authorised collection agent, the manufacturers need to pay a collection fee to the waste agent. However, if the collection fee is paid without obtaining the VAT invoice from the agents, the manufacturer will be subject to an additional 15% withholding tax (WHT).
7. Exporting the waste only attracts zero VAT if it's justifiable from the costs and benefits of fabric waste exports.

b) Regulatory implications in setting up a waste recycling unit in Cambodia

Based on the Notification No. 36, dated 21 January 2021 defines small-medium size businesses (SMEs) using two criteria: i) the number of employees and ii) either the value of turnover (revenue) or assets, whichever is higher. They are categorized into agriculture, industry and commerce sectors. Below are the criteria of SMEs.

Table 15 SME definitions in Cambodia

Industry	Number of employees		Turnover (USD)		Or	Assets (USD)	
	Small	Medium	Small	Medium		Small	Medium
Agriculture	5 - 49	50 - 199	62,250 - 250,000	250,001 - 1,000,000		50,000 - 250,000	250,001 - 500,000
Industry	5 - 49	50 - 199	62,500 - 400,000	400,001 - 2,000,000		50,000 - 500,000	500,001 - 1,000,000
Service and Commerce	5 - 49	50 - 199	62,500 - 250,000	250,001 - 1,500,000		50,000 - 250,000	250,001 - 500,000

Source: Office of the Council of Ministers

Based on the estimated revenue figures (see Chapter 11), the **Fabric Waste Recycle Pilot (FWRP) facility qualifies as a medium-size enterprise in Cambodia**. Also, **the recycling facility can apply to be registered as an Export Qualified Investment Project (Export QIP).**

As a new enterprise, FWRP must carry out the following procedures

1. Register the name with the Ministry of Commerce (MoC).
2. Fifteen days after registering the name with the MoC, the new enterprise should register with the General Department of Taxation (GDT) to obtain the tax patent and VAT certificate.
3. You should go to the Ministry of Labour and Vocational training (MLVT) to be registered under labour laws and:
    - provide a workbook for Khmer employees
    - provide work permits for foreign employees
    - register under the National Social Security fund if the unit has more than eight employees.
4. As the company recycles waste, the new enterprise must request permission or a license from the Ministry of Environment (MoE) and follow the following guidelines and processes
    a. Sub-decree on Solid Waste Management, No. 36 (1999)
    b. Declaration on Industrial Solid Waste Collection and Transport in Phnom Penh and Kandal, No. 148 (2002)
    c. Inter-Ministerial Declaration of Ministry of Interior-Ministry of Environment on Waste and Solid Waste
5. **The company has to also seek permission from MISTI for its recycling activities, especially importing recycling machines.**

Taxation and incentives: Based on the Law of Investment published in 2021, Article 26 states that investment activities registered as QIP are entitled to choose basic incentives under the following two options.

1. **Option 1:**
    - Income tax exemption period is for three to nine years, depending on the sector and investment activities, from the time of earning its first income. The Law on Financial Management and/or the Sub-decree determine sector and investment activities, as well as the period of income tax exemption.
    - Prepayment tax exemption during the income tax exemption period
    - Minimum tax exemption provided that an independent audit report has been carried out
    - Export tax exemption, unless otherwise provided in other laws and regulations.
    - After the income tax exemption period expires, the QIP's income tax should be 25% for the first 2 years, 50% in the 3rd and 4th year, and 75% in the 5th and 6th year of the 20% corporate income tax rate on taxable income. Please refer to the summary below for the income tax exemption calculation:

- Year 1: 25% × 20% CIT
- Year 2: 25% × 20% CIT
- Year 3: 50% × 20% CIT
- Year 4: 50% × 20% CIT
- Year 5: 75% × 20% CIT
- Year 6: 75% × 20% CIT

2. Option 2: Special depreciation

- Deduction of capital expenditure through special depreciation as stated in the tax regulations
- Eligibility of deducting up to 200% of specific expenses incurred for up to nine years. Sectors and investment activities, specific expenses, as well as the deductible period, will be determined in the Law on Financial Management and/or the Sub-decree
- Prepayment tax exemption for a specific period of time based on sectors and investment activities to be determined in the Law on Financial Management and/or the Sub-decree
- Minimum tax exemption provided that an independent audit report has been carried out
- Export tax exemption, unless otherwise provided in other laws and regulations.

In addition to the incentives stated in paragraph 1 of this Article:

a. An Export QIP and Supporting Industry QIP are entitled to customs duty, special tax and VAT exemptions for the import of construction materials, construction equipment, production equipment and production inputs

b. A Domestically Oriented QIP is entitled to customs duty, special tax and VAT exemptions for the import of construction materials, construction equipment and production equipment. The incentives for production inputs will be determined in the Law on Financial Management and/or the Sub-decree.

A QIP located in a special economic zone is entitled to the same incentives and protections as other QIP set forth in this law.

Other incentives

In addition to the basic incentives set out in Article 26 of this law, investment activities registered as QIP receive these additional incentives.

1. VAT exemptions for the purchase of locally made production inputs for implementing the QIP
2. A deduction of 150% from the tax base for any of the following activities
   a. Research, development and innovation
   b. Human resource development through the provision of vocational training and skills to Cambodian workers/employees
   c. Construction of accommodation, food courts or canteens where reasonably priced foods are sold, nurseries and other facilities for workers/employees
   d. Upgrades to machinery to serve the production line and
   e. Provision of welfare for Cambodian workers/employees, such as comfortable means of transportation to commute from their homes to factories, accommodation, food courts or canteens where foods are sold at reasonable prices, nurseries and other facilities
3. Entitlements to income tax exemption for the Expansion of QIP which are determined in the Sub-decree.

Also, according to **Sub-decree No. 124[13] on Tax incentives for small and medium-sized enterprises operating in defined priority sectors,** which includes **waste recycling,** further fiscal benefits include:

- an exemption from tax on income for three years for newly registered enterprises or from the date of updating the tax registration for existing enterprises
- an exemption from tax on income for five years for newly registered enterprises or from the date of updating the tax registration for existing enterprises that meet one of the following criteria:
  i. the enterprise uses at least 60% local raw materials
  ii. the enterprise increases its number of employees by 20%, or

[13] Government of Cambodia, Sub-decree promulgated in October 2018

iii. the enterprise is in the SME cluster zone

- Incentives for deductible expenditure include:
  i. a 200% weighted tax-deductible expense for IT-based accounting software and training and staff technical training
  ii. a 200% weighted tax-deductible expense for accounting training or technical skills training for employees, and
  i. a 150% weighted tax-deductible expense for equipment or new technology that increases productivity

Conclusion: Present taxation and regulatory policy is complex and some of the points (e.g. 5% fabric waste) are not sufficiently aligned to the present condition of the industry. Simplification of the policies, making it more practical and incentivizing the circular economy initiatives might help the industry in improving its environmental sustainability.

10. Alternative use of rPET fiber

A major alternative usage of rPET fiber may be in Non-woven applications. Non-wovens is a category of textiles that are manufactured to achieve a specific functional purpose. As per ISO 9092, nonwoven is defined as "*manufactured sheet, web or batt of directionally or randomly oriented fibers, bonded by friction, and/or cohesion and/or adhesion, excluding paper and products which are woven, knitted, tufted, stitch-bonded incorporating binding yarns or filaments or felted by wet-milling, whether or not additionally needled. The fibers may be of natural or man-made origin. They may be staple or continuous filaments or be formed in situ".*

In conventional yarn and fabric manufacturing, higher variation of staple length of the fiber deteriorates certain quality parameters including tenacity and imperfections. The same is true for rPET fibers coming out from the Green Machine and we have commented on the inferior quality of the yarn and fabric manufactured using 100% rPET fibers in previous chapters.

As the higher variation of staple length of fiber has insignificant / nil impact on the quality of nonwoven materials manufactured using mechanical, thermal and chemical bonding process, rPET fibers may be used in manufacturing of a large number of non-woven products. Some of the potential major end segments and respective application areas are mentioned below:

Figure 11 Potential applications of Green machine fibre in nonwovens

Automotive	**Medical textiles**	**Home textiles**	**Other areas**
• Filters	• Wipes	• Carpets	• Packaging
• Automobile carpets	• Scrubbers	• Home furnishings	• Acoustic ceiling
• Seat covers	• Padding	• Floor coverings	• Shoe lining/slippers
• Headliners	• Wadding	• Fillings for pillows, mattress, sofa, quilts and soft toys	• Artificial turf
• Boot liner	• Hygiene fabrics		• Teabags
			• Insulation

Source: Secondary research

Desired properties in recycled fibres for usage in nonwovens: The typical properties required in fibres are high abrasion resistance, high UV resistance, high stiffness, excellent light fastness, high moldability, light weight, and thermal stability. The rPET fibers may be chemically processed to achieve these desired properties.

The global nonwoven market is estimated at US$ 35 bn. in 2022 and is growing at a CAGR of 6.77% (2020-2025). Synthetic fibres are the primarily used in the manufacturing of non-wovens with over 99% share in global production (in volume terms). Polypropylene dominates this segment with over ~64% share (in volume terms) followed by Polyester with ~18% share.[14]

Recently multiple PET recycling companies are targeting nonwoven applications as their target market base. Current global market size (2022) for some of the application areas of recycled polyester fibre in nonwovens is quite significant. Following are some of the examples:

- Automotive filters: ~US$ 18.6 bn.[15]
- Automotive upholstery: ~US$ 33 bn.[16]
- Medical wipes: ~US$ 6.6 bn.[17]
- Carpets: ~US$ 1.2 bn.
- Fillings: ~USD 165 mn.[16]

[14] Non-woven fabric market - growth, trends, and forecast (2020 - 2025) – Mordor Intelligence
[15] 2022 Global Innovative Markets Forecast – Automotive Filters
[16] Barnes Report 2022 Global High Tech and Emerging Markets Report – Automotive Upholstery and Fillings
[17] Aritzon Advisory & Intelligence Global Outlook & Forecast 2021−2026 – Antiseptic Wipes

Case studies of some notable recycled fibres and nonwoven fabric manufacturers is illustrated below

Leigh Fibers is one of the leading textile waste and by-product re-processor in North America. The company reprocesses all kind of fibres including polyester. The recycled polyester from Leigh Fibres is used in applications such as batting and wadding (furniture), industrial filters, acoustic insultation, etc.

Ganesha Ecosphere, which is one of leading recycled PET manufacturer in India is supplying recycled polyester fibre (PET bottle) for use in non-woven air filter fabric, geo textiles, carpets and car upholstery and fillings (pillows, duvets and toys).

Green Fiber is a Romania based 100% recycled polyester manufacturer with an installed annual processing capacity of processing 80,000 tons fiber. Company's products are used in non-woven based applications including fillings for pillows, mattresses or furniture, filtration, hygiene and healthcare, insulation, and automotive components.

TWE Group engages in the manufacture and sales of carded nonwoven fabrics worldwide. It offers needle-punched nonwovens from both virgin and recycled fiber mixtures. The company offers automobile interiors, filtration, construction, and personal care products. It serves markets dealing in automotive, hygiene, healthcare, building, and filtration.

11. Financial feasibility analysis

The report has so far focused on understanding the technical, market, and regulatory viability of this ambitious project. Although the output of the previous chapter are aligned in favour of the Green Machine, for the Green machine to have a quick industry adoption and reach economies of scale, it is imperative for it to be financially viable for an investor. This chapter explores the financial feasibility of the Green machine. The project team has used stakeholders (both project and industry stakeholders) verified assumptions and inputs to carry out the analysis.

a) Key assumptions and inputs

Minimum economic size of the plant is one of the major parameter for carrying out the financial feasibility of any manufacturing facility. **Based on the calculations, minimum two Green machines need to be installed to make the pilot plant financially viable.**

As mentioned in the concluding statement of the location analysis, given the challenges with sorting of waste at both source (i.e. a garment factory) and waste processing unit, it is advised that the Green machine facility is located along with a large garment factory. Since Phnom Penh is the main garment manufacturing hub in Cambodia, the **proposed facility is assumed to be set-up in the Phnom Penh cluster as an extension of an already established large garment unit. In this case, no input logistics cost is taken into calculations.**

Size of the garment factory for running a 2 Green machine facility: *The installed daily capacity of the two Green machines is 3 tons of fabric waste per day. To feed this facility, a garment factory producing ~80,000 pieces per day (Polo T-shirts considered for the calculation) will be required. The relevant assumptions and calculation has been shown in the table below:*

Table 16 Garment factory size calculations

Parameters	Particulars	Unit
Assumptions		
Weight of a T-shirt	250	gm
Cutting waste standard	15	%
SAM of a T-shirt	10.4	minutes
No. of operating shifts	1	
Shift time	480	minutes
Calculations		
Cutting waste generated	38	gm/t-shirt
No. of T-shirts required	80,000	pieces per day
No. of T-shirts produced on a single machine per day	46	no.
No. of machines required to produce 3 tons waste	1,740	no. of machines

Source: PwC analysis

We have bifurcated the assumptions and inputs under different heads as follows:

General assumptions

Table 17 General assumptions

Parameters	Value
No. of working hours per day	24
No. of working shift per day	3
No. of working hours shift per shift	8
No. of working days per week	7
No. of working days per year	350
Batch time - Hydrothermal (hrs.)	3
Batch time - Decoloring (hrs.)	5
rPET output from Hydrothermal machine	98%

Raw material inputs

Table 18 Raw material inputs

Parameters	Hydrothermal system	De-coloring system
Fabric (kg/batch)	210	145
Organic acid consumption (kg/batch)	49	
Absorbent consumption (kg/batch)		7.4
Anti-back staining agent (kg/batch)		12
Energy consumption (kWh/batch)	505	607
Water consumption (kg/batch)	249	200
Process water consumption (kg/batch)	249	200
Rinsing water consumption (kg/batch)	6,000	1,500

Price assumptions

Table 19 Price assumptions

Parameters / Year	1	2	3	4	5	6	7	8	9	10
Green fibre sales price (USD/kg)	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1
Cellulosic powder (USD/kg)	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6
Electricity cost (USD/kWh)	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.15
Water cost (USD/litre)	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003

Inflation assumptions

Table 20 Inflation assumptions

Parameters	Values
Sales price escalation	3%
Raw material cost escalation	2%
Salary growth	5%
Wage growth	5%

Opex assumptions

Table 21 Opex assumptions

Parameters/ Years	1	2	3	4	5	6	7	8	9	10
Fabric waste price (USD/kg)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
Organic acid (USD/kg)	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59
Absorbent cost (USD/kg)	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59
50% anti-back staining agent (USD/kg)	2.00	2.04	2.08	2.12	2.16	2.20	2.24	2.28	2.33	2.37
Packing expenses (USD/kg)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
SGA expenses (% of total sales)	2.0%									
Stores and Spares (% of total sales)	0.5%									
Maintenance (% of total sales)	0.5%									

Taxation assumptions

Table 22 Taxation assumptions

Parameters	Value	Remarks
Custom duty on import of machinery	0%	Assuming the factory qualifies as an Export QIP
Custom duty/ tax on purchase of fabric waste	0%	
Custom duty/Tax on sales of recycled polyester	0%	
Custom duty/Tax on sales of cellulosic powder	0%	
Corporate tax on manufacturing industries	20%	

Contingency assumptions

Table 23 Contingency assumptions

Parameters	Values
Domestic machinery and equipment	5%
Imported machinery and equipment	8%

Working capital assumptions

Table 24 Working capital assumptions

Parameters	Days
Raw material	30
WIP	15
Finished Goods	10
Debtors	45
Creditors	30

Financing assumptions

Table 25 Financing assumptions

Parameters	Days
Debt	50%
Equity	50%
Margin Money	25%
Interest on Term Loan	6.8%
Interest on Working Capital Financing	6.5%

b) Production planning and sales

Capacity and Product mix:

- No. of Green machines installed: 2
- Capacity: 3 tons per day

Table 26 Product mix

Parameters	Values
Dyed polyester-cotton blend (65:35)	
Polyester	65%
Cotton	35%
Output from one hydrothermal machine	
Dyed recycled polyester output (kg/batch)	134
Cellulosic powder (kg/batch)	74
Output from one decoloring machine	
Decolored recycled polyester (kg/batch)	134

Utilization levels

Table 27 Utilization levels

Parameters	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Utilization levels	75%	85%	90%	95%	95%	95%	95%	95%	95%	95%

Annual production output

Table 28 Annual production output

Prod. volume (kg)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Decolored recycled polyester output	561,834	636,745	674,201	711,656	711,656	711,656	711,656	711,656	711,656	711,656
Cellulosic powder	308,700	349,860	370,440	391,020	391,020	391,020	391,020	391,020	391,020	391,020

Annual sales

Table 29 Annual sales

Sales - USD Mn.	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Decolored recycled polyester output	1,317,501	1,539,456	1,680,542	1,828,897	1,885,593	1,944,046	2,004,311	2,066,445	2,130,505	2,196,551
Cellulosic powder	129,654	151,496	165,381	179,980	185,559	191,312	197,242	203,357	209,661	216,160
Total Sales	**1,447,155**	**1,690,952**	**1,845,923**	**2,008,877**	**2,071,152**	**2,135,358**	**2,201,554**	**2,269,802**	**2,340,166**	**2,412,711**

c) Raw material requirement and cost

Annual raw material requirement

Table 30 Annual raw material requirement

Parameters (Kg)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
PC Blended Fabric Waste (65:35)	882,000	999,600	1,058,400	1,117,200	1,117,200	1,117,200	1,117,200	1,117,200	1,117,200	1,117,200
Organic acid	205,800	233,240	246,960	260,680	260,680	260,680	260,680	260,680	260,680	260,680
Absorbent	18,673	21,163	22,408	23,653	23,653	23,653	23,653	23,653	23,653	23,653
50% anti-back staining agent	30,240	34,272	36,288	38,304	38,304	38,304	38,304	38,304	38,304	38,304

Annual raw material cost

Table 31 Annual raw material cost

Parameters (USD)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
PC Blended Fabric Waste (65:35)	11,760	13,581	14,653	15,761	16,061	16,366	16,677	16,994	17,317	17,646
Organic acid	102,900	118,836	128,217	137,911	140,532	143,202	145,923	148,695	151,520	154,399
Absorbent	9,337	10,783	11,634	12,513	12,751	12,993	13,240	13,492	13,748	14,009
50% anti-back staining agent	60,480	69,846	75,360	81,058	82,598	84,168	85,767	87,396	89,057	90,749
Total cost	**184,477**	**213,046**	**229,864**	**247,244**	**251,942**	**256,729**	**261,607**	**266,577**	**271,642**	**276,803**

d) Utilities calculation

Annual utilities requirement

Table 32 Annual utilities requirement

Parameters	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Energy requirement (kWh/year)	4,670,400	5,293,120	5,604,480	5,915,840	5,915,840	5,915,840	5,915,840	5,915,840	5,915,840	5,915,840
Water requirement (litres/year)	1,885,800	2,137,240	2,262,960	2,388,680	2,388,680	2,388,680	2,388,680	2,388,680	2,388,680	2,388,680

Annual utilities cost

Table 33 Annual utilities cost

USD/year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Energy cost	637,777	738,086	798,032	860,202	878,433	897,070	916,124	935,603	955,518	975,881
Water cost	448	518	559	602	614	626	639	652	665	678

e) Manpower calculation

Manpower requirement

Table 34 Manpower requirement

Type/Designation	No. of personnel required per Green machine per shift	Shift/ General	Total no. of personnel required for 2 machines	Salary/Wages (USD/month)
Head of operations	1	General	1	2,500
Admin officer	1	General	1	1,000
Accounts officer	1	General	1	1,000
Sales and marketing officer	1	General	1	1,000
Procurement in-charge	1	General	1	1,000
Supervisor	1	General	1	800
Hydrothermal process operators (per machine)	3	Shift	18	194
Decoloring process operators (per machine)	2	Shift	12	194
Security	1	Shift	3	194
Total			**39**	

Manpower cost

Table 35 Manpower cost

USD/year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Salary cost	87,600	91,980	96,579	101,408	106,478	111,802	117,392	123,262	129,425	135,896
Wage cost	76,824	80,665	84,698	88,933	93,380	98,049	102,952	108,099	113,504	119,179
Total cost	**164,424**	**172,645**	**181,277**	**190,341**	**199,858**	**209,851**	**220,344**	**231,361**	**242,929**	**255,076**

f) Total operational expenditure

Table 36 Total operational expenditure

USD/year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Raw material	184,477	213,046	229,864	247,244	251,942	256,729	261,607	266,577	271,642	276,803
Power	637,777	738,086	798,032	860,202	878,433	897,070	916,124	935,603	955,518	975,881
Manpower	164,424	172,645	181,277	190,341	199,858	209,851	220,344	231,361	242,929	255,076
Water	448	518	559	602	614	626	639	652	665	678
Packing expense	17,411	20,107	21,694	23,335	23,778	24,230	24,690	25,159	25,637	26,124
Total cost	**1,004,536**	**1,144,402**	**1,231,427**	**1,321,724**	**1,354,626**	**1,388,507**	**1,423,403**	**1,459,352**	**1,496,391**	**1,534,562**

g) Working capital requirement

Table 37 Working capital requirement

Parameters	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Raw material	17,925	20,709	22,353	24,053	24,521	24,997	25,483	25,979	26,484	26,999
WIP	43,672	49,771	53,567	57,506	58,943	60,423	61,947	63,516	65,134	66,801
Finished Goods	41,347	48,313	52,741	57,396	59,176	61,010	62,902	64,851	66,862	68,935
Debtors	186,063	217,408	237,333	258,284	266,291	274,546	283,057	291,832	300,878	310,206
Creditors	15,812	18,261	19,703	21,192	21,595	22,005	22,423	22,849	23,284	23,726
Current Liabilities	289,007	336,201	365,993	397,240	408,931	420,976	433,388	446,178	459,358	472,941
Current Liabilities	15,812	18,261	19,703	21,192	21,595	22,005	22,423	22,849	23,284	23,726
Net Working Capital	**273,194**	**317,940**	**346,291**	**376,048**	**387,336**	**398,971**	**410,965**	**423,329**	**436,075**	**449,215**
Increase in Working Capital	273,194	44,745	28,351	29,757	11,288	11,635	11,994	12,364	12,746	13,140
Margin Money	**68,299**	**79,485**	**86,573**	**94,012**	**96,834**	**99,743**	**102,741**	**105,832**	**109,019**	**112,304**
Increase in margin money	68,299	11,186	7,088	7,439	2,822	2,909	2,999	3,091	3,186	3,285
Bank Finance	**204,896**	**238,455**	**259,718**	**282,036**	**290,502**	**299,228**	**308,224**	**317,497**	**327,056**	**336,911**
Interest on Working Capital	**13,318**	**15,500**	**16,882**	**18,332**	**18,883**	**19,450**	**20,035**	**20,637**	**21,259**	**21,899**

h) Capex calculation

Capex summary

Table 38 Capex summary

Parameters	Cost (USD)
Land	631,200
Building	473,400
Machinery	2,474,000
Miscellaneous	114,000
Pre-project expenses	669,630
Contingency	140,570
Total Capex	**4,502,800**

Land requirement and cost

Table 39 Land requirement and cost

Parameters	Particulars
Hydrothermal separation system (including the cellulosic powder drying system) - sq. mtr	400
PET De-coloring system (including the hydroextractor and dryer system) - sq. mtr	400
Raw material (waste fabric, chemical and absorbent) and finished good storage - sq. mtr	60
Fabric cutter - sq. mtr	60
Fibre shredding machine system - sq. mtr	132
Open space (50% total of machine space) - sq. mtr	526
Built up area - sq. mtr	**1,578**
Land requirement (considering 50% open land) - sq. mtr	**3,156**
Land rates - USD/sq. mtr	200
Land cost - USD	**631,200**
Construction rates	300
Construction cost – USD	**473,400**

Machinery requirement and cost

Table 40 Machinery requirement and cost

Particulars	No. of units/machine set	Amount (USD)
Hydrothermal machine components		
Processing Vessel Machine - 135°C	2	375,000
Loading Conveyor	1	24,500
Hydro Extractor	1	128,000
Drying Machine - 150 kgs	1	53,000
Vacuum Dryer	1	21,000

Rotary Drum Screen	1	19,000
Basket Filter	4	
Filter Gasket	4	
Scrapper Self Auto Clean Filter	2	53,000
Filter Elements for the Scraper Filters	2	
Total cost for hydrothermal system (2 sets of machines installed)		**1,347,000**
Decoloring machine components		
Dyeing Machine - 180°C	2	515,000
Absorbent Filters	2	27,000
Total Cost (2 sets of machines installed)		**1,084,000**
Other major machines		
Fabric Cutter	1	3,000
Mechanical fibre shredding machine	1	40,000
Total machinery cost		**2,474,000**

Miscellaneous fixed assets

Table 41 Miscellaneous fixed assets

Particulars	No. of units	Amount (USD)
DG set	1	40,000
Boiler	1	45,000
Compressor	1	10,000
Electrical panels and fittings	1	7,000
Piping and other auxiliary equipment	1	12,000
Total cost		**114,000**

Pre-project expenses

Table 42 Pre-project expenses

Particulars	Amount (USD)
Project Management & Engineering	403,500
Travelling	31,000
License fee	235,130
Grand Total	**669,630**

Contingency expenses

Table 43 Contingency expenses

Parameters (USD)	Total Cost	Firm Cost	Non- Firm Cost
Land	631,200	631,200	
Building Cost	473,400		473,400
Plant and Machinery			
Imported	1,390,000	1,390,000	
Miscellaneous Fixed Assets			
Indigenous	114,000		114,000
Total	**2,608,600**	**2,021,200**	**587,400**
Contingency on Imported Items			111,200
Contingency on All Other Non-firm Items			29,370
Total Contingency			**140,570**

i) Depreciation schedule

Rate of depreciation

Table 44 Rate of depreciation

Parameters	Annual Rate of Depreciation	Annual Cost of Depreciation (USD)
Factory Building	5.0%	23,670
Other Fixed Assets	20.0%	22,800

Depreciation schedule for 10 years

Table 45 Depreciation schedule for 10 years

Machine/ Year	1	2	3	4	5	6	7	8	9	10
Gross Value of Machinery	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000	2,474,000
Depreciation per year	247,400	247,400	247,400	247,400	247,400	247,400	247,400	247,400	247,400	247,400
Cumulative depreciation	247,400	494,800	742,200	989,600	1,237,000	1,484,400	1,731,800	1,979,200	2,226,600	2,474,000
Net Asset Value	**2,226,600**	**1,979,200**	**1,731,800**	**1,484,400**	**1,237,000**	**989,600**	**742,200**	**494,800**	**247,400**	**-**

Building/ Year	1	2	3	4	5	6	7	8	9	10
Gross Value of Building	473,400	473,400	473,400	473,400	473,400	473,400	473,400	473,400	473,400	473,400
Depreciation per year	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0	23,670.0
Cumulative dep	23,670	47,340	71,010	94,680	118,350	142,020	165,690	189,360	213,030	236,700
Net Asset Value	**449,730**	**426,060**	**402,390**	**378,720**	**355,050**	**331,380**	**307,710**	**284,040**	**260,370**	**236,700**

MFA/ Year	1	2	3	4	5	6	7	8	9	10
Gross Value of MFA	114,000	114,000	114,000	114,000	114,000	114,000	114,000	114,000	114,000	114,000
Depreciation per year	22,800.0	22,800.0	22,800.0	22,800.0	22,800.0	0.0	0.0	0.0	0.0	0.0
Cumulative dep	22,800	45,600	68,400	91,200	114,000	114,000	114,000	114,000	114,000	114,000
Net Asset Value	**91,200**	**68,400**	**45,600**	**22,800**	**0**	**0**	**0**	**0**	**0**	**0**

j) Loan schedule

Table 46 Loan schedule

Parameters	Value
Total term loan - USD	2,251,400
Equity Contribution - USD	2,251,400
Total Project Cost - USD	**4,502,800**
Total Duration of loan (years)	10
No of Instalment per year	4
Total Months of loan	40
Total Moratorium Period including construction - Installments	8
Loan repayment instalments	32
Installment Amount - USD	**70,356**

Parameters / Year	1	2	3	4	5	6	7	8	9	10
Outstanding amount at the beginning of year	-	2,251,400	2,251,400	1,969,975	1,688,550	1,407,125	1,125,700	844,275	562,850	281,425
Loan Issued	2,251,400	-	-	-	-	-	-	-	-	-
Repayment	-	-	281,425	281,425	281,425	281,425	281,425	281,425	281,425	281,425
Outstanding amount at the end of year	2,251,400	2,251,400	1,969,975	1,688,550	1,407,125	1,125,700	844,275	562,850	281,425	-
Interest on loan	**153,095**	**153,095**	**145,919**	**126,782**	**107,645**	**88,508**	**69,371**	**50,234**	**48,018**	**18,469**

k) Profit and loss statement – for 10 years

Table 47 Profit and loss statement

Parameters / Year	1	2	3	4	5	6	7	8	9	10
Net revenue from sales	**1,447,155**	**1,690,952**	**1,845,923**	**2,008,877**	**2,071,152**	**2,135,358**	**2,201,554**	**2,269,802**	**2,340,166**	**2,412,711**
Opex										
Raw material	184,477	213,046	229,864	247,244	251,942	256,729	261,607	266,577	271,642	276,803
Power	637,777	738,086	798,032	860,202	878,433	897,070	916,124	935,603	955,518	975,881
Wages	76,824	80,665	84,698	88,933	93,380	98,049	102,952	108,099	113,504	119,179
Water	448	518	559	602	614	626	639	652	665	678
Packing expense	17,411	20,107	21,694	23,335	23,778	24,230	24,690	25,159	25,637	26,124
Stores and Spares	7,236	8,455	9,230	10,044	10,356	10,677	11,008	11,349	11,701	12,064
Maintenance	7,236	8,455	9,230	10,044	10,356	10,677	11,008	11,349	11,701	12,064
Total COGS	**931,408**	**1,069,332**	**1,153,307**	**1,240,405**	**1,268,859**	**1,298,058**	**1,328,026**	**1,358,788**	**1,390,368**	**1,422,793**
SGA	28,943	33,819	36,918	40,178	41,423	42,707	44,031	45,396	46,803	48,254
Salary	87,600	91,980	96,579	101,408	106,478	111,802	117,392	123,262	129,425	135,896
Total Opex	**1,047,951**	**1,195,131**	**1,286,805**	**1,381,991**	**1,416,760**	**1,452,567**	**1,489,450**	**1,527,446**	**1,566,596**	**1,606,943**
EBITDA	399,204	495,821	559,118	626,886	654,392	682,790	712,104	742,356	773,569	805,768
EBITDA Margin	**28%**	**29%**	**30%**	**31%**	**32%**	**32%**	**32%**	**33%**	**33%**	**33%**
Depreciation	293,870	293,870	293,870	293,870	293,870	271,070	271,070	271,070	271,070	271,070
Interest										
On Term Loan	153,095	153,095	145,919	126,782	107,645	88,508	69,371	50,234	48,018	18,469
On WC loan	13,318	15,500	16,882	18,332	18,883	19,450	20,035	20,637	21,259	21,899
Total Interest	**166,413**	**168,595**	**162,801**	**145,114**	**126,528**	**107,958**	**89,406**	**70,872**	**69,277**	**40,368**
PBT	(61,080)	33,356	102,447	187,902	233,994	303,762	351,628	400,414	433,223	494,330
PBT %	**-4%**	**2%**	**6%**	**9%**	**11%**	**14%**	**16%**	**18%**	**19%**	**20%**
Tax Payable	0	6671	20489	37,580	46,799	60,752	70,326	80,083	86,645	98,866

PAT	(61,080)	26,685	81,958	150,322	187,195	243,010	281,303	320,331	346,578	395,464
PAT %	**-4%**	**2%**	**4%**	**7%**	**9%**	**11%**	**13%**	**14%**	**15%**	**16%**

I) Financial ratio calculations

Payback

Table 48 Payback calculations

Parameters / Year	1	2	3	4	5	6	7	8	9	10
Cash profit	232,790	320,555	375,828	444,192	481,065	514,080	552,373	591,401	617,648	666,534
Cumulative cash profit	232,790	553,345	929,173	1,373,365	1,854,430	2,368,510	2,920,883	3,512,284	4,129,932	4,796,466
Project cost	4,502,800									
Payback years	**9.6**									

IRR

Table 49 IRR calculations

Parameters / Year	0	1	2	3	4	5	6	7	8	9	10
Inflows											
PAT		(61,080)	26,685	81,958	150,322	187,195	243,010	281,303	320,331	346,578	395,464
Depreciation		293,870	293,870	293,870	293,870	293,870	271,070	271,070	271,070	271,070	271,070
Total Inflow		**232,790**	**320,555**	**375,828**	**444,192**	**481,065**	**514,080**	**552,373**	**591,401**	**617,648**	**666,534**
Capex	**(4,502,800)**		0	0	0	0	0	0	0	0	0
Change in net working capital		273,194	44,745	28,351	29,757	11,288	11,635	11,994	12,364	12,746	13,140
Total out flow		**273,194**	**44,745**	**28,351**	**29,757**	**11,288**	**11,635**	**11,994**	**12,364**	**12,746**	**13,140**
Net Inflow	**(4,502,800)**	**(40,404)**	**275,810**	**347,477**	**414,434**	**469,778**	**502,445**	**540,379**	**579,037**	**604,902**	**653,394**

Parameters	Value
Cost of debt	7%
Cost of equity	3%
Capital structure breakup	
Debt	50%
Equity	50%
WACC	4.2%
Expected growth rate	2%

Terminal value - USD	30,020,815
IRR (post Tax)	**22.5%**

Net present value

Table 50 Net present value calculations

Parameters – USD / Year	1	2	3	4	5	6	7	8	9	10
NPV of FCF generated	(38,768)	253,926	306,954	351,278	382,065	392,086	404,614	416,005	416,990	432,180
Discounted Terminal value										**19,856,916**
Total DCF	20,289,096	253,926	306,954	351,278	382,065	392,086	404,614	416,005	416,990	20,289,096
Company valuation										**23,174,245**

m) Sensitivity analysis

A business is impacted by multiple external and internal factors. For a new business investment, it is essential to understand its feasibility under different circumstances that are both positive and negative in its nature. To realize the viability of this proposed Green machine pilot facility, a sensitivity analysis has been carried on the basis of two broad factors:

1. **Location:** Chip Mong Insee's Kampot plant has been considered as alternative location. This facility has solar power as source of energy
2. **Sales price and raw material cost:** Alternative price/cost points and growth/de-growth percentage is taken in consideration.
3. **Different input fabric waste composition:** Two more fabric compositions i.e. PC (50:50) and PC (60:40) have been taken in consideration.

Sensitivity analysis with alternative location and solar power as source of energy

Assumptions:

- The garment manufacturing plant will deliver sorted and labelled fabric wastes to CMI and will not pay any fee to CMI for collecting those fabric wastes. CMI will also not pay any amount to garment manufacturing plants for collecting sorted and labelled fabric wastes. So, the cost of fabric waste becomes zero for CMI.
- The collected waste has to be transported from Phnom Penh (the main garment manufacturing hub) to Kampot (location of CMI's cement plant). Thus logistics cost of transporting waste ~129 km is considered in this case.
- CMI has a solar power plant. The market rate of solar power has been considered for calculating energy cost[18].

Table 51 Assumptions - CMI Kampot Location

Parameters	Unit	Particulars
Distance between CMI Kampot and Phnom Penh	km	129
Logistics Rate	USD/ton/km	0.12
	USD/ton	15.48

[18] Source of solar power sales price: https://chinadialogue.net/en/energy/opinion-cambodia-can-secure-reliable-electricity-without-new-coal-2/#:~:text=In%20Cambodia%2C%20solar%20and%20wind%20power%20are%20the%20cheapest%20source,and%20Xekong%20thermal%20power%20plants.

Parameters	Unit	Particulars
Solar power market rate	USD / kWh	0.069

Source:CMI

Table 52 Alternative location with solar power as source of energy

Parameters / Year	1	2	3	4	5	6	7	8	9	10
EBITDA (USD)	702,732	847,578	939,971	1,037,973	1,074,764	1,112,662	1,151,697	1,191,895	1,233,288	1,275,903
EBITDA Margin	**49%**	**50%**	**51%**	**52%**	**52%**	**52%**	**52%**	**53%**	**53%**	**53%**
PAT (USD)	194,466	308,679	387,277	479,878	524,196	587,626	633,711	680,714	715,121	772,358
PAT Margin	**13%**	**18%**	**21%**	**24%**	**25%**	**28%**	**29%**	**30%**	**31%**	**32%**
Payback (Years)	**6.3**									
IRR (post tax)	**30.1%**									
NPV (USD)	**37,283,207**									

Conclusion: Significant positive changes in financial feasibility of the proposed unit is observed.

Change in product price and raw material cost

Two sets of assumptions i.e. Optimistic and pessimistic have been incorporated in the model and compared with the financial ratios of the base model to understand the change in financial stability. The table below highlights the assumptions taken for carrying out the sensitivity analysis:

Table 53 Assumptions for sensitivity analysis

Parameters / against the base case	Optimistic case	Pessimistic case
Sales price – base year	+5%	-5%
Raw material cost – base year	-5%	+5%
Sales price growth over the next 10 years	5%	1%
Raw material cost increase over the next 10 years	1%	3%

Optimistic scenario

Table 54 Optimistic scenario

Parameters / Year	1	2	3	4	5	6	7	8	9	10
EBITDA (USD)	463,690	604,820	715,403	838,185	915,399	997,085	1,083,478	1,174,825	1,271,385	1,373,432
EBITDA Margin	**31%**	**34%**	**36%**	**38%**	**39%**	**41%**	**42%**	**44%**	**45%**	**46%**
PAT (USD)	2,321	113,214	206,036	318,083	394,429	492,557	576,173	663,712	741,844	846,189
PAT Margin	**0.2%**	**6%**	**10%**	**14%**	**17%**	**20%**	**22%**	**25%**	**26%**	**28%**

Parameters / Year	1	2	3	4	5	6	7	8	9	10
Payback (Years)	**7.4**									
IRR (post tax)	**29.0%**									
NPV (USD)	**38,269,101**									

Pessimistic scenario

Table 55 Pessimistic scenario

Parameters / Year	1	2	3	4	5	6	7	8	9	10
EBITDA (USD)	334,717	386,066	402,490	417,161	398,479	378,837	358,197	336,516	313,752	289,861
EBITDA Margin	**24%**	**24%**	**24%**	**23%**	**22%**	**21%**	**19%**	**18%**	**17%**	**15%**
PAT (USD)	(125,060)	(75,560)	(53,001)	(20,258)	(20,020)	1,643	259	(2,449)	(23,230)	(17,809)
PAT Margin	**-9.1%**	**-4.8%**	**-3.1%**	**-1.1%**	**-1.1%**	**0.1%**	**0.0%**	**-0.1%**	**-1.2%**	**-0.9%**
Payback (Years)	**>10 years**									
IRR (post tax)	**11.6%**									
NPV (USD)	**9,181,187**									

Conclusion: The key impact of the pessimistic scenario is on the net income and payback period. On the positive side, the operating income is still at healthy levels. This indicates that the economies of scale and reduction of initial capex will be crucial for the long term financial sustainability of the Green machine.

Different input fabric waste composition

This analysis is carried out to understand the feasibility of the proposed Green machine pilot plant under different input fabric compositions. We have considered the following two compositions for assessment:

- **Composition 1**: 50% Polyester : 50% Cotton
- **Composition 2:** 60% Polyester : 40% Cotton

Feasibility with Composition 1:

Parameters / Year	1	2	3	4	5	6	7	8	9	10
EBITDA (USD)	158,132	214,138	251,620	292,244	309,377	327,080	345,368	364,252	383,745	403,860
EBITDA Margin	**13%**	**15%**	**16%**	**18%**	**18%**	**18%**	**19%**	**19%**	**20%**	**20%**
PAT (USD)	**(300,238)**	**(246,091)**	**(202,610)**	**(144,084)**	**(108,282)**	**(49,124)**	**(12,197)**	**20,249**	**37,194**	**76,490**
PAT Margin	**-25%**	**-18%**	**-13%**	**-9%**	**-6%**	**-3%**	**-1%**	**1%**	**2%**	**4%**
Payback (Years)	**>10 years**									
IRR (post tax)	**13.1%**									
NPV (USD)	**11,290,120**									

Feasibility with Composition 2:

Parameters / Year	1	2	3	4	5	6	7	8	9	10
EBITDA (USD)	318,847	401,927	456,619	515,339	539,387	564,220	589,859	616,321	643,628	671,798
EBITDA Margin	23%	25%	26%	27%	28%	28%	28%	29%	29%	30%
PAT (USD)	(140,799)	(59,793)	609	61,792	95,922	148,907	184,283	220,304	243,450	289,139
PAT Margin	-10%	-4%	0%	3%	5%	7%	9%	10%	11%	13%
Payback (Years)	**>10 years**									
IRR (post tax)	**19.9%**									
NPV (USD)	**19,246,074**									

Conclusion: Similar to the impact of pessimistic scenario in the previous section, the key impact of the blend proportion change is also on the net income and payback period. In order to achieve financial feasibility (for processing blend compositions containing polyester content lower than 65%), economies of scale and lower initial capex are required.

Likelihood of scenarios

The scenario of alternative location (CMI) with solar energy as source of power is moderately likely. Both optimistic and pessimistic scenarios covering raw material cost and output price are highly unlikely. Since PC blend proportion of 50:50 and 60:40 are very commonly used in the industry, it is highly likely that Green machine facility will have to process these materials.

12. Environmental considerations

To understand whether a business investment is truly sustainable or not, it is important to understand its environment sustainability. This report so far, has discussed the technical and financial feasibility of the Green machine pilot plant. This chapter focuses on the environmental sustainability of the proposed unit. To understand this, 3 key parameters have been analysed i.e. GHG emissions, wastewater generated, and solid waste generated. The table below highlights the annual output values of these parameters for a pilot unit with two Green machines.

- At operational stability (i.e. 4th year onwards), the facility is estimated to generated 3.2 million kg of CO_2.
- The major water consuming process is rinsing. However, this water can be reused after filtration. The other water consuming process is the dilution of acids, which is used in hydrothermal separation and de-coloration process.
- The Absorbent has to be replaced after every 27 batches. This residual is hazardous in nature as it has absorbed various dyes and chemicals in the de-coloration process. The handling of this hazardous material has to be done in accordance with *ZDHC Wastewater Guidelines Version 2.0. which includes Sludge Disposal Pathways, Parameters and Limits*.[19]

Table 56 Emission from the Green machine facility

Parameters - annual generation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
GHG Emissions (million kg CO_2)	2.5	2.8	3.0	**3.2**	3.2	3.2	3.2	3.2	3.2	3.2
Wastewater generated (if rinsing water is reused) - million kg	1.9	2.1	2.3	**2.4**	2.4	2.4	2.4	2.4	2.4	2.4
Wastewater generated (if rinsing water is not reused) - million kg	33.4	37.8	40.1	**42.3**	42.3	42.3	42.3	42.3	42.3	42.3
Absorbent to be dumped / incinerated (kg)	18,673	21,163	22,408	**23,653**	23,653	23,653	23,653	23,653	23,653	23,653

Source: HKRITA and PwC Analysis

[19] https://downloads.roadmaptozero.com/output/ZDHC-Wastewater-Guidelines

13. Potential risks and possible mitigation measures

The Green Machine Pilot Plant will be a first of its kind initiative in Cambodia. To ensure the success of this initiative, it is imperative to understand the underlying potential risks and develop possible mitigation measures to overcome those risks. Following potential risks and possible mitigation measures have been identified through discussions with relevant stakeholders, in-depth secondary research and the visit to the Indonesian facility:

a) Fabric wastes containing polyester blended yarns, having less than 3% Elastane content and without dope dyed fibers are ideal as feed material for the Green Machine. Coated, laminated and quilted fabrics are not suitable for Green machine. If unsuitable fabric wastes are fed in the Green Machine, it may either clog the machine and stop operation (applicable for coated fabric, laminated fabric, quilted fabric, fabric containing more than 3% Elastane) or the output material may be similar to feed material (applicable for 100% polyester fabric). The De-coloring machine can't take out dyes from dope dyed fibers.

This potential risk may be mitigated by proper sorting of pre-consumer fabric wastes in the factories and storing of those fabric wastes with proper labelling of fiber content, type of fabric and type of dyeing process used.

b) The nominated fabric waste collectors charge a fee for collecting the fabric wastes from the factories and the present taxation process is not in favor of the apparel manufacturers. It causes increase in operating costs. As most of the apparel manufacturers of Cambodia are manufacturing basic garments, which is a highly price sensitive business, this increase in operating cost may reduce the cost competitiveness and thus the manufacturers may not be keen to use the formal system of waste disposal.

This potential risk may be mitigated by a combination of following measures:

1. Green Machine Pilot Plant may collect the sorted and labelled fabric wastes from the apparel manufacturing units by paying appropriate price
2. Government of Cambodia may like to revise the taxation policies related to disposal of fabric wastes and may like to provide fiscal incentives to units which are using the formal waste disposal system and segregating the fabric wastes as per its quality. Government may also allow the garment manufacturers a reasonable amount of fabric waste for converting imported fabrics into garment.

14. Conclusion

Setting up of a fabric waste recycling pilot unit in Cambodia using Green Machine Technology is feasible from technical, economic and institutional perspective provided following mandatory and optional major conditions are followed:

1. Major mandatory conditions

    a. Fabric wastes, sorted by fiber composition and fabric quality, are available and all the fabric wastes are properly labelled

    b. rPET, the output of the Green Machine, are used along with other virgin fibers for manufacturing of yarn. However, it may be used as 100% in select non-woven applications or as filling materials.

2. Major optional conditions (preferred)

    a. Polyester content of the fabric waste is 60% or lower and it is applicable for each type of yarn (if multiple yarns are used in developing the fabric)

    b. Dope dyed fibers are not used as feed material for the Green Machine

    c. Woven and knitting fabrics developed using rPET fibers are not used as outer layer of the garment / home textile materials

Disclaimer:

The feasibility study is based on primary and secondary research – within the limited data availability. The information and the data in the feasibility study have been conducted on the basis of information shared by stakeholders, publicly available information; internal data and other sources believed to be true and are for general guidance only, but which may have not been verified independently. While every effort is made to ensure the accuracy and completeness of information contained, the company takes no responsibility and assumes no liability for any error/omission or accuracy of the information. Recipients of this material should rely on their own judgments and conclusions from relevant sources before making any decisions.

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