ANALYSIS OF ALTERNATIVES

Legal name of applicant(s):	*Vlisco Netherlands BV*
Submitted by:	*Vlisco Netherlands BV*
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Substance:	*Trichloroethylene*
Use title:	*Use of trichloroethylene as a solvent for the removal and recovery of resin from dyed cloth*
Use number:	*Use 1*

DECLARATION

We, Vlisco Netherlands BV, claim the information blanked out in the "public version" of the Analysis of Alternatives and which is specified in Annex, confidential. We hereby declare that, to the best of our knowledge as of May 20th 2014 the information is not publicly available, and in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to the information claimed confidential without our written consent or that of the third party whose commercial interests are at stake.

Signature:

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IMPORTANT NOTE FOR THE READER OF THIS AoA REPORT

If this report is read from a printed document, there a number of pictures in this report which are best viewed in colour. The report contains all the information suggested to be included in the ECHA template.

For this report:

- Vlisco Netherlands B.V is referred to as “Vlisco”

Use of decimal marks in this report:

- 10,000 refers to ten thousand; and
- 100.25 refers to one hundred and a quarter.

Use of footnotes and endnotes

- Footnotes are at the bottom of the page and are numbered with roman numbers (i, ii, iii, …)
- Endnotes are references of confidential sections in the document and are numbered with Arabic numbers (1,2,3,…)

List of abbreviations

AfA	Application for Authorisation
AoA	Analysis of Alternatives
ATEX	ATmosphères EXplosibles (1999/92/EG & 94/9/EG)
CAS	Chemical Abstracts Service
CBA	Cost Benefit Analysis
CI	Confidence Interval
CMR	Carcinogenic, Mutagenic or toxic to Reproduction
CSR	Chemical Safety Report
DRC	Democratic Republic of the Congo
DU	Downstream User
EC	European Commission
ECHA	European Chemicals Agency
EDC	Endocrine Disrupting Compound
EEA	European Economic Area
ES	Exposure scenario
EU	European Union
EU COM	European Commission
FTE	Full time equivalent, measure of headcount
GDP	Gross Domestic Product
HM	Her Majesty
LAD	Latest Application Date
LE	Legal entity
LoA	Letter of Access
LR	Lead Registrant
MDL	Method detection limit

NPV	Net Present Value
OC	Occupational Condition
OPEX	Operating costs
PPE	Personal Protection Equipment
PERC	Tetrachloroethylene, also called Perchloroethylene
PPM	Parts Per Million
PSIS	Pre Submission Information Session
PV	Present Value
R&D	Research & Development
RAC	Risk Assessment Committee
RCR	Risk Characterisation Ratio
REACH	Registration, Evaluation, Authorisation & restriction of CHemicals
RMM	Risk Management Measures
RSP	Rotary Screen Printing
SCOEL	Scientific Committee for Occupational Exposure Limits
SVHC	Substance of Very High Concern
SEA	Socio Economic Analysis
SHS	Switchable Hydrophobicity Solvent
SOP	Standard Operating Procedures
TCE	Trichloroethylene
WIPO	World Intellectual Property Organisation
WTP	Willingness To Pay

1. SUMMARY

The applicant – Vlisco Netherlands BV (hereafter called Vlisco) - has been operating since 1846, creating unique textiles (often termed 'Real Dutch Wax' textiles) designed for the West and Central African market, which originate from traditional wax techniques (cfr. Batik in Indonesia). In the cloth dyeing process, Vlisco is a down-stream user of Trichloroethylene (TCE). Vlisco uses Trichloroethylene (TCE) as a solvent in the cloth dyeing process, in two ways:

USE 1: The use of TCE as a solvent for the removal and recovery of resin from dyed cloth

USE 2: The use of TCE as a solvent in a process to recover and purify resin from process water

This analysis of alternatives, investigates the possible alternatives for Use 1: the use of TCE (Trichloroethylene EC n° 201-167-4) as a solvent in a closed system for the removal of the synthetic resin from cotton cloth, as part of a textile dyeing process. A separate analysis of alternatives has been prepared for Use 2. Some of the process equipment is shared between the two uses, which complicates the search for potential alternatives.

The resin used in Vlisco's dyeing process of cotton cloth allows the creation of a textile with very specific features. These are unique to Vlisco and account for the product's popularity and premium market image in African countries. They are also extremely difficult, and in some cases impossible, to obtain with different techniques. The applicant has a history of many years of research and development to try to find an alternative for the use of TCE. Efforts have been made to find alternative solvents and alternative production techniques to obtain the desired effect. In addition, other types of resist and other printing techniques have been investigated. However, the high throughput rate of the process, the specific requirements imposed by the properties of the resin and the economic need to recover both solvent and resin, are difficult conditions to meet and make finding a technically and economically feasible alternative, which provides the same or an equivalent final product, extremely challenging.

In this report, several alternatives to TCE in Use 1 are considered and six of the most promising are explored in detail. The following types of alternatives were considered:

- Other solvents
- Other resists
- Alternative techniques to create the same product look
- Relocation of the production site

The results of the analysis show that there is at present no suitable alternative to TCE in Use 1. All alternatives are not yet technically feasible, and (except in one case) could only be adopted (if at all) after several years of development and implementation. All options would be associated with significant losses in revenue for Vlisco during these implementation periods, and/or increases in investment and operating costs. Estimates of these costs have been made, along with an assessment of the risk reduction potential, for a number of the most likely alternatives. These estimates are subject to considerable uncertainty but are the best available. The intention was to identify the option which Vlisco would adopt if it is not permitted to continue its use of TCE beyond the Sunset Date in April 2016. The results of this analysis are summarised in Table 1. The combination for the two uses is also provided, since the two processes are integrated.

Table 1: Summary analysis of alternatives to the use of TCE in Use 1 and 2[1]

Option	Use 1 Risk reduction potential	Implementation period (years)	Present value cost (mio €)	Use 1 and 2 Present value cost Total (mio €)
PERC PERC	Low-zero. similar hazard profile to TCE	2.5	[redacted]	[redacted] 94%
PERC Solvent free extraction	Low-zero. similar hazard profile to TCE	2.5	[redacted]	[redacted] 100%
Flammable solvent Flammable solvent	Low-zero – additional fire risk	6	[redacted]	[redacted] 101%
Flammable solvent Solvent free extraction	Low-zero – additional fire risk	7	[redacted]	[redacted] 112%
Rosin Solvent free extraction	Minimal risks from use	9	[redacted]	[redacted] 110%
Switchable solvent Switchable solvent	Minimal risks from use	12+	[redacted]	[redacted] 109%
RSP	Minimal risks from use	1		[redacted] 244%

Note
1. Alternatives related to Use 1 a mentioned in **bold**.
2. Total costs for the option for Use 1 and Use 2 is provided relative to the cost of the most likely option in case the use of TCE would no longer be allowed after sunset date.

The easiest alternative to adopt would be to switch the entire production process away from one based on resist-based dyeing to one using screen- or inkjet printing. This option could be adopted in one year and would be available in time for the TCE Sunset Date. However, using a printing technique would involve losing all of the key features which generate demand for the current Vlisco product, and make the new product commensurable with existing Chinese fabrics sold at much lower prices. These prices are below the production cost of Vlisco's comparable Java fabrics, and would not be profitable for Vlisco. Therefore, significant financial losses would result – as indicated by the very high estimated net present cost. These losses would not be commercially sustainable and Vlisco's business would be forced to close.

Options based on the adoption of flammable solvents, rosin and switchable solvents are all estimated to generate significant costs. This largely reflects the long implementation periods predicted for these options. Long implementation periods, and, in particular, the inability to implement Use 1 before the Sunset Date would necessitate a complete shutdown of Vlisco's Real Dutch Wax production operation. This would result at a minimum in the loss of profits for each year closure– estimated at around [redacted][2] (in 2014 terms), which serves to underline the importance of implementation times to the overall cost of alternatives to TCE for Use 1. In addition, there would be costs associated with redundancy of permanent staff, and then rehiring and training prior to (re-)start-up, as well as testing the new processes and returning the installation to an commercial operational basis. Costs associated with mothballing the plant are not included in the estimates, which assume that sales will return to pre-closure levels even after an absence of the market of 12 years (and possibly longer). There is a risk that the market would never return to its previous level, and might even effectively disappear. The costs of these options which include (in some cases significant durations of) closure are certainly underestimated, therefore, and possibility significantly.

The costs of the options based on the alternative solvent Perchloroethylene (‘PERC’) are consequently lower, reflecting their relatively short times for implementation for Use 1. However, both involve implementation after the TCE Sunset Date, and hence costs are still large in absolute terms due to the loss of profit associated with the need for temporary shutdown. . In addition, the shorter shut-down period means that it would not make sense to make permanent staff redundant, only to have to rehire and (possibly) retrain them only months later, so Vlisco would propose to retain permanent staff even during production shut-down. Although this would avoid any social costs associated with redundancy, it significantly increases the costs of the PERC options in the short term.

Nevertheless, PERC-based option for Use 1 (with PERC or solvent free extraction for Use 2) is clearly the least cost alternative to TCE compared with the other alternatives available. As a result, PERC would be the option which Vlisco would adopt for Use 1 if it could no longer use TCE after the Sunset Date (i.e. the non-use scenario in the event that authorisation is refused). Indeed, preliminary plans have already been initiated to implement PERC for Use 1 in the event TCE use must stop after the Sunset Date, in an attempt to minimize the implementation period and thereby reduce its costs.

The cost of the option based on a so-called ‘switchable’ solvent is estimated to be very significant, reflecting the long implementation period expected with this option due to the significant technical uncertainties which would need to be resolved for it to be technically feasible. This option would not be adopted in the current non-use scenario, therefore. However, the switchable solvent alternative is the only viable option which is expected could maintain product quality and also result in a net reduction in operating costs (due to reduced energy consumption) following transition. The net present value of the option, if it could be adopted without the need for downtime (e.g. in combination with a positive authorisation decision for instance) might be relatively low compared with the other options (perhaps towards €5m). These costs (although very uncertain) might fall further if implementation periods could be shortened, to the extent that the investment at least has the potential to become economically feasible from Vlisco’s perspective. As a result, Vlisco intends to investigate switchable solvents as a long-term means to substitution away from chlorinated solvent-based processes. The current long-term development plan could lead to this suitable alternative being available in approximately 12 years. This is based on a scenario in which all milestones are met on time, and is therefore likely to be optimistic.

2. ANALYSIS OF SUBSTANCE FUNCTION

2.1. Background

The applicant – Vlisco Netherlands BV (hereafter called Vlisco) - has been operating since 1846, creating unique textiles designed for the West and Central African market, which originate from traditional wax techniques (cfr. Batik in Indonesia). In 1846, a Dutch entrepreneur Pieter Fentener van Vlissingen established the textile company P.F. van Vlissingen & Co, which is now called the Vlisco Group (Vlisco), in the Dutch city of Helmond.

According to World Intellectual Property Organisation (WIPO)[i], "*although Vlisco originally sold batik in Europe, the fabrics were also used for bartering by traders on Dutch ships travelling from the East Indies and stopping over on the West African coast. When African women in the region first encountered the textile, they fell in love with it and subsequently embraced it as their own*". In particular, African women showed a preference for the deeper, bolder colours and prints with a crackled effect produced by the use of resins in the dyeing process.

Over time, these fabrics have acquired cultural (and fashion) significance within these regions of Africa, where they are worn on special occasions[ii] (e.g. community events, weddings, and birthdays) and at religious ceremonies. Figure 1 depicts some traditional wax fabric designs.

Figure 1: Typical Vlisco fabrics made into clothing
Source: Vlisco[iii]

A critical and unique selling factor is that Vlisco fabrics are produced in the Netherlands using a special (unique) wax process enabling the product to be sold as "real Dutch wax" fabrics, a name which is synonymous with traditional techniques and high quality. In terms of branding, "Real

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[i] The World Intellectual Property Organisation (WIPO) – "The fabled cloth and its IP future" - http://www.wipo.int/ipadvantage/en/details.jsp?id=3501

[ii] Waxprints im soziokulturellen Kontext Ghanas, Magisterarbeit, Gabriele Gerlich, 2004

[iii] http://www.vlisco.com/new-arrivals/en/page/538/#/?FK_7=42&CPI=0

Dutch Wax" is as identifiable as the Vlisco brand name (according to WIPO[i], some customers know these fabrics as Real Dutch Wax whilst others know the products to be produced by Vlisco).

To be classed as 'real Dutch wax' fabric, beside the important boundary condition that the substrate is cotton, the following criteria must be met:

- Designed indigo dyeing
- Broad colour range; vivid and bold colours (reactive, azoic and pthalogene dyes)
- A controlled matching of front and back: same colour or half tones colours
- Non repeating unique bubbling patterns originating from the design
- Crackle effect
- A soft appearance of the design by blurred edges

It is only with Vlisco's batik-based technique that this specific combination of design features of the textile can be achieved (see Appendix C). These properties are the basis for the evaluation of the technical feasibility of an alternative to create an equivalent final product.

2.2. Overview

Used for centuries, batik is fabric made with a dyeing technique using a resist to generate patterns in different colours. Traditionally, to make batik, wax is used to block areas of the cloth, which then resist the dye and thus maintain their original colour. The mechanised version of this approach (used by the applicant), known as a mechanical resist (the wax - or resin - prevents the dye from entering the cloth via a mechanical closure of the fibre), allows for one or more colouring effects to be added to the first layer of colour (referred to as the base layer). This process can be repeated many times to create a plethora of colours and designs.

The fact that resin is used for the resistant function allows for (1) the use of more different type of dyes and (2) its specific partial removal (also called 'breaking-off') creating bubble shaped random patterns. Although the shape of the patterns is random, the location can be defined and is used as specific feature during the design of the image for the textile. This concept is generally referred to as "the perfect imperfection": the random bubbles patterns located on exact places as designed.

The applicant's technique gives the fabric a unique look and feel, which has led to its popularity and esteem in West and Central Africa. A vibrant and receptive market for this printed cloth exists in Africa. In order to maintain its presence in the market, the applicant started adapting their batiks to African fashion, which showed a preference for deeper, bolder colours and prints with a bubbled and crackled effect. These textiles, mainly used for clothing, often use nature, geometry, religious and cultural symbols to indicate societal and marital status, mood, political and religious beliefs[iv].

[iv] Waxprints im soziokulturellen Kontext Ghanas, Magisterarbeit, Gabriele Gerlich, 2004

2.3. Process description

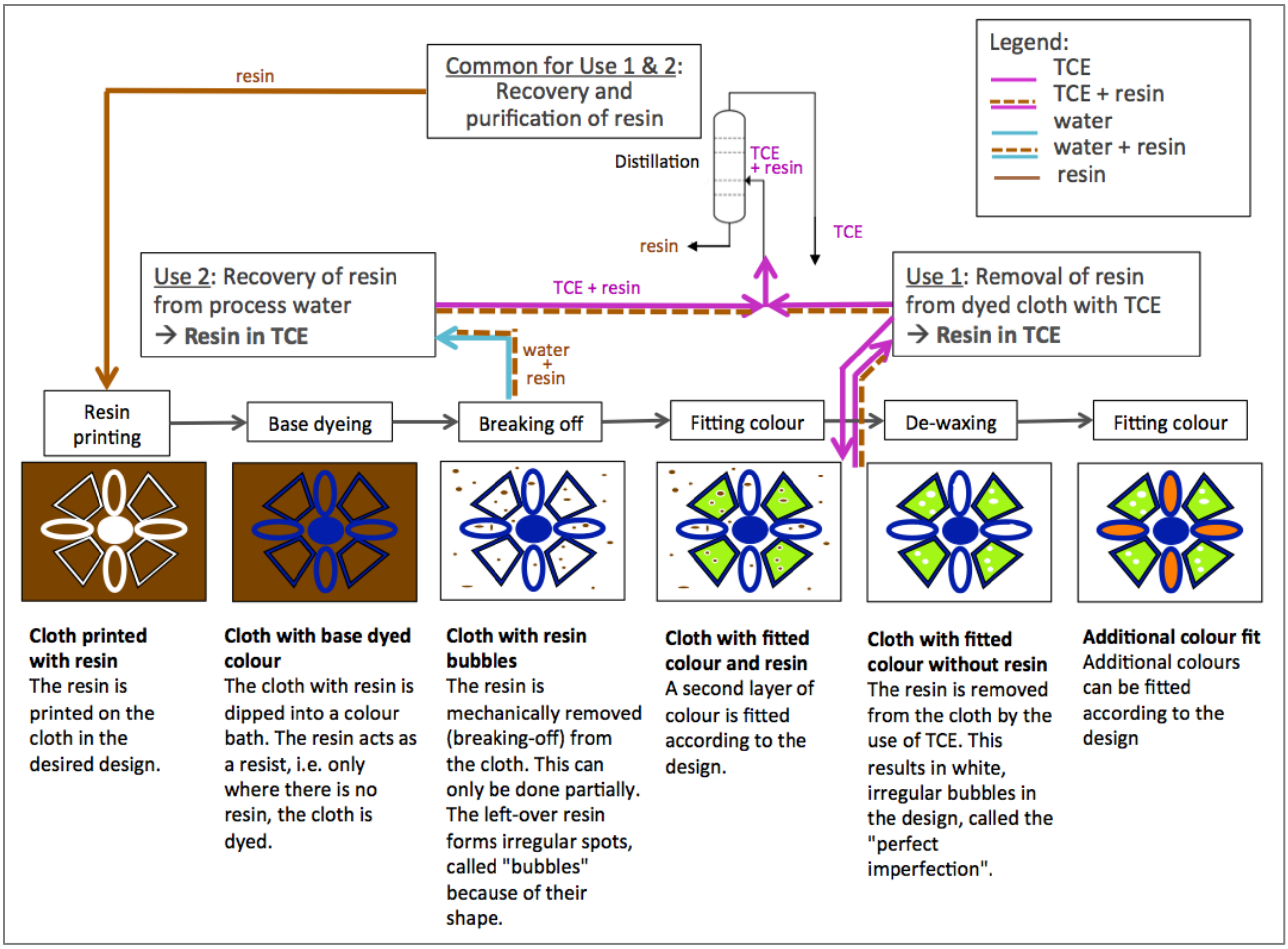


Figure 2: Overview of Use 1 & 2 and the link between the two

The process undertaken by Vlisco to produce its ‘Real Dutch Wax’ fabrics is summarised in Figure 2, and can be seen to comprise a number of distinct stages In the first stage of the process (resin printing, see box 1 in Figure 2) a resin is printed on a cotton cloth. Resin acts as a resist during the base-dyeing step (box 2 in Figure 2). In the next step (Breaking-off, see box 3 in Figure 2), a part of the resin is removed. The breaking-off is done in large “washing” machines where, through a combination of mechanical force and water, the resin is partially removed from the cloth. The remaining resin on the cloth coagulates into small spheres and again acts as a resist, for the next colouring step (colour fitting, see box 4 in Figure 2), where the typical bubbling pattern is made. Also during this step, the edges of the remaining resin on the cloth forms micro cracks, which create the specific blurred effect during the next colouring step. When the base colours and first fitting colours are on the cloth, the remaining resin is removed from the cloth using TCE (de-waxing, see pink arrows for TCE between box 4 and box 5 of Figure 2). The removal of the resin from the cloth and the recovery (see common part in Figure 2) of the resin and solvent are the main elements of Use 1.

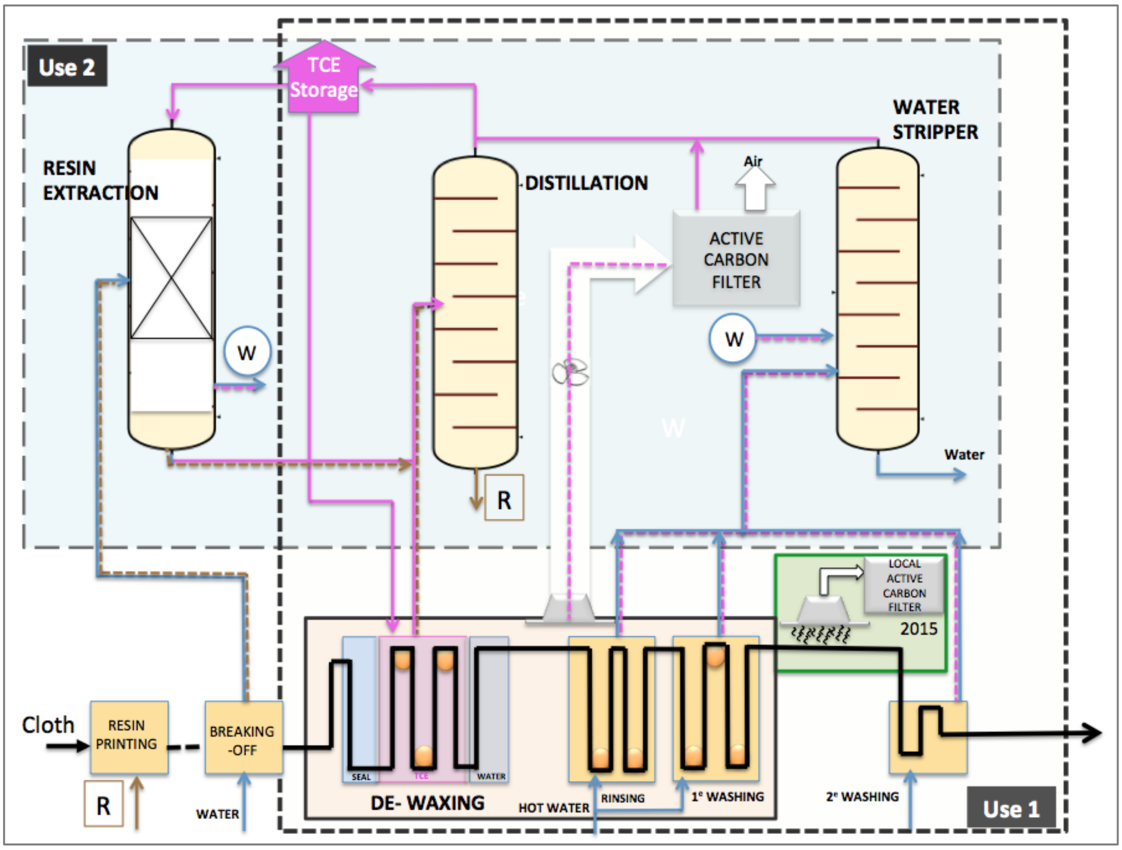


Figure 3: Overview of Vlisco's Use 1 and 2

In Figure 3 the different process steps of Use 1 and 2 are shown. Here it can already be seen that certain process steps are common for the two Uses. Neither of the two Uses can occur without the common parts. The common steps of the 2 uses are (see Figure 3):

- **Storage** of TCE
- The removal of TCE from the waste gases from Use 1 and Use 2 by an **active carbon filter**
- Water solvent separation (TCE containing water from Use 1 and Use 2 is stripped with steam in the **water stripper**)
- Resin-solvent separation by **distillation**

This equipment can be shared because similar process streams occur in both uses. Sharing these uses results in a significant lower investment cost.

Supply of TCE is done using state of the art "SAFETAINERS" to enable emission free loading and unloading of TCE. The system is equipped with dry couplings and a vapour return system to eliminate any emissions during unloading of TCE. The SAFETAINERS are sent back to the supplier of TCE for re-use. By doing so, there is no waste from packaging contaminated with TCE.

Storage of the TCE is done in vessels at atmospheric pressure. The vapour overhead of these vessels is connected to an active carbon filter.

The cost of resin as an input to production is also an important driver for its recovery and reuse. The average price over the period 2008-2012 was €1,810 per ton. Current prices are higher.. Recovery and reuse can thereby result in significant cost savings. If no recovery took place, raw material costs would increase by 27-30%, and there would be significant increases in the costs of water purification and waste treatment.

2.4. Process conditions

An overview of the technical process for both uses of TCE including the abatement systems (air treatment and water treatment) is provided in Figure 3. The annual use of TCE in both Use 1 and 2 was 8 in 2013 and will be 4 tonnes as of 2014.The main elements relevant for Use 1 are:

- **De-waxing** the cloth by dissolving the resin in TCE
  - **Extraction**
  - **Rinsing**
  - **Washing**
- **Distillation**: Separation and recovery of the TCE and resin (common with Use 2)
- **Air treatment**: Active carbon filter to remove and recover TCE from vapours (common with Use 2)
- **Water treatment**: Removal and recovery of the TCE from the wash water (common with Use 2)

De-waxing (Figure 3**, process to remove the wax from the cloth):**
Yearly production of dyed cloth is about 30 mio yards. The cloth is made of closely woven cotton yarns. The porosity inside the yarn is very low. The solid resin is deeply penetrated into the yarns and is only accessible for removal by dissolving. The process for the removal of the resin from the cloth is a continuous dissolving process (**extraction**). For the removal of the resin, the cloth is fed continuously into a closed system. The velocity of the cloth through the de-waxing system is about [redacted][3], with a contact time below [redacted][4]. The process operates at a sub-atmospheric pressure. Vapours are extracted from this closed system to the active carbon filter. The pressure in the closed system is automatically controlled. In that closed system, the cloth is passed through a TCE bath [redacted][5] followed by a TCE removal step (**rinsing**) using dry steam and water ([redacted])[6]. The cloth is transported through the closed system by means of transport rolls. The mechanical forces applied on the cloth are low to minimize the wear on the cloth and the release of fibres. After the rinsing there is a **first washing step** ([redacted])[7] within the closed system. The cloth leaves the closed system and is fed continuously in a **second washing step** ([redacted])[8]. In this washing phase, excess dye is removed. All wash water is collected in a closed system and is treated in a water-stripping unit (common with Use 2), before the water is discharged to the sewer and municipal waste-water treatment. At places outside the closed system where the temperature of the cloth containing TCE is above ambient, local exhaust ventilation (LEV) will be present with efficiency above 90%. The vapours from the LEV are treated with an installation with a removal efficiency of at least 99% (dedicated active carbon system with incineration of waste active carbon). The investment for this modification has been approved in Q1 2014.

Distillation (Figure 3**, distillation column):**
The TCE and resin are separated by distilling the solution coming from the extraction step in an installation shared with Use 2. The concentration of TCE in the recovered resin needs to be sufficiently low to avoid exposure of workers to TCE during the (re-)use of the resin. The maximum concentration of TCE in the resin is below 0.01%. The distillation occurs at elevated temperature, i.e. above the initial decomposition temperature of TCE. A significant proportion (11%) of the annual losses of TCE is due to the decomposition of TCE at the distillation stage. This decomposition is confirmed by the presence of HCl in the system, which is then neutralised through the addition of NH_4OH. The separation and recovery of the resin and TCE happen in a closed system operating at atmospheric pressure and with all vents connected to the active carbon filter.

Air treatment (Figure 3 **active carbon filter):**
The vapour outlet of the water-stripping tower is connected to the active carbon filter,,which is shared with Use 2. The average concentration of TCE at the outlet of the active carbon filter is 6 mg/m^3, and never exceeds 20 mg/m^3; the maximum concentration allowed in the exploitation permit is 50 mg/m^3. The active carbon filter consists of two parallel units. While one unit is in operation, removing the TCE from the vapour stream, the TCE is removed from the other unit and will be put in service again when the first unit is saturated with TCE. The removed TCE is recovered and is sent to storage for subsequent reuse.

Water treatment (Figure 3 **water stripper):**
All water streams containing TCE are treated in a continuous **water-stripping** unit, to remove the TCE before discharge to the municipal sewer system. This unit operates at 100°C and steam is injected continuously into the water to evaporate and remove the solvent. This unit is common with Use 2. The average TCE concentration in the waste water is 50 microgram/l. The load of TCE in the waste water is about 100 kg/year. The maximum concentration of TCE in the waste-water allowed in the permit is 300 microgram/l and the maximum load is 400 kg/year.

The recovery rates of resin and TCE need to be as high as possible to reduce costs and environmental impacts. It is not possible to calculate a separate mass balance of sufficient accuracy possible for Use 1 only. The overall (complete process including Use 1 and Use 2) recovery rate of the resin is above 95%, and the recovery rate of TCE is above 99.99%.
Extraction, distillation and water-stripping are continuously operating, closed process units controlled from a central control room. State of the art equipment is used such as magnetically coupled closed pumps to prevent fugitive emissions. On-line detection systems with active alarms are in place to ensure early detection of any accidental releases of TCE in an early phase. Integrity of the system is managed via inspection systems on the vessels and piping system and via a state of the art leak detection and repair program (LDAR).

2.5. Tasks performed by the Substance and Substance function data

Table 2: Function of the substance

Function aspect	Explanation
Task performed	Use 1: *Use of trichloroethylene as a solvent for the removal and recovery of resin from dyed cloth* TCE is used as a solvent for the removal of a resin from a dyed cotton cloth. The resulting TCE-resin solution is separated into resin and TCE; both products are re-used with a very high level of recovery in the dyeing process.

What critical properties and quality criteria must the substance fulfil	Hazard properties
	• Non flammable
	• Less hazardous than TCE; Classification of TCE
	  ○ Skin Irrit. 2 H315
	  ○ Eye Irrit. 2 H319
	  ○ STOT SE 3 H336
	  ○ Muta. 2 H341
	  ○ Carc. 1B H350 (Harmonized)
	  ○ Aquatic Chron 3 H412
	• Seveso substance: NO
	
	Substance Properties:
	• Interaction with dyestuff (indigo, reactive, azoic & pthalogene): solvent should have no interaction with the used dyes
	• Interaction with cotton cloth: solvent or any other part of the process should have no interaction
	• Stability: solvent should be sufficiently stable in contact with water and within the temperature ranges used. Initial decomposition temperature > 120°C. Solvent should have a stable composition during recycling.
	• Solubility speed: the substance must be able to solubilize the resin fast, to minimize the equipment size for a given capacity.(Table 5)
	• Solubility of the resin in the substance: resin must be soluble to high loads in the substance to minimize solvent throughput
	• Boiling point: defines the design and operational costs of recovery installation. Boiling point should be as low as possible. (Table 5)
	• Non-flammable substance: present installation not suitable for flammable substances
	• Heat of evaporation: defines the energy requirement for the recovery. The heat of evaporation should be as low as possible.
	• Solubility in water: solubility of the substance in water should be low in order to minimize the concentration in waste water
	• Density difference between water and solvent: allows separation of water and solvent by gravity . (Table 5)
	
	In case the current resin is replaced by an other resist to allow other solvents to be used, certain properties of the new resist need to be taken into account:
	• [redacted][9]
	In case the substance is replaced by implementation of another technique, the impact of such an alternative on Use 2 and more specifically on the properties of the final product have to be taken into account.
	Criteria for acceptability of the final product are summarized in Appendix C

Function conditions	• The installation operates fully continuously 24/24, 7/7. • The resin is removed from the cloth by a continuous, dissolving

Function aspect	Explanation
	process with a contact time [redacted][10]. The resin is recovered (overall) for 95%; the solvent is recovered for more than 99,99% (Use 1 and 2 combined). • Water from the washing and rinsing step, containing TCE, is steam stripped before discharge. All vapours are treated by BAT (Best Available Technique) active carbon filters, which are regenerated to recover the TCE. • Monitoring systems at emission points and for the equipment (LDAR: leak detection and repair) are in place to guard the overall performance of the processes. On-line detection systems, which activate additional ventilation systems, are in place to protect workers and minimize emissions in case of incidental releases (alarm at 50 mg/m3). • A significant part of the TCE consumption is due to decomposition in the process. TCE is used above the lower temperature for decomposition. • In 2013 8T of TCE was consumed in total. Forecast for 2014 and thereafter is 4 tonne/year as result of further process improvement.
Process and performance constraints	• Thermal stability of the resin at conditions (see 2.4. Process conditions) of recovery of the solvent and resin is crucial. Conditions required for the separation of the solvent-resin mixture should not affect the stability of the resin. • Remaining concentration of solvent in the resin should be sufficiently low to avoid exposure to the solvent in the resin printing process. • Chemical and physical properties of the solvent define the design and operation of the extraction process (Table 5), (see also row 2 in this table: “What critical properties and quality criteria must the substance fulfil”).
Is this substance associated with another process that could be altered so that the use of the substance is limited or eliminated	• The use of TCE in Use 1 is linked to extraction of resin from process water in Use 2. Alternative processes for this Use 2 are described in the AoA of Use 2. In case a suitable alternative could be found for Use 1, which does not make use of a resist, Use 2 would no longer be relevant. • A drop-in replacement for the solvent must be suitable for Use 1 and 2. A solvent, which is an alternative for Use 2 but not for Use 1 would lead to significant additional investment and operational costs to split and operate the current common equipment for both uses. • An alternative resist, which can be used in Use 1 without the use of a solvent, will put specific requirements on Use 2
Customer requirements	• Most and for all, the cloth needs to be free of resin and TCE. • There is a clear requirement from the customer of the Vlisco product for the specific Vlisco designs, which are linked to the “Real Dutch Wax” and the associated mechanical resist technology. See Appendix C
Industry or sector requirements	The concentration of TCE in the wastewater needs to be below 300 microgram/l. The average concentration of TCE at the outlet of the active carbon filter to air is 6 mg/m^3, never exceeding 20 mg/m^3. The limit in the exploitation permit is 50 mg/m^3. Alternative solvents will have other specific emission limits that have to be met. Specifically emission limits to water and air need to be taken into account.

In the current installation, TCE is used as a solvent for the resin in both the resin removal from the cloth (Use 1) and in the resin extraction from the water (Use 2) processes. Both uses share parts of the installation. The suitability of an alternative for Use 1 needs to take into account the effect on

Use 2. Specifically, if two different solvents were selected as alternative for the two uses, an additional resin-solvent separation unit and a separate air treatment unit would be required.

3. IDENTIFICATION OF POSSIBLE ALTERNATIVES

3.1. List of possible alternatives

Vlisco has been making considerable efforts in finding and researching possible alternatives for TCE over the last 35 years. In 2004 and 2013 external professional parties have been involved in reviewing and providing additional input on possible alternatives for TCE to be used in the process at Vlisco. The list of possible alternatives has been summarized and completed by a systematic study made by an external party in 2013 (Appendix A, document a3).

The first focus of this analysis of alternatives is on substances or processes which are an alternative to the substance function, namely to remove the resist completely from the dyed and printed cloth. A second group of alternatives concerns the combination of a different resist (currently a resin) and a suitable solvent or other removal technique. It needs to be noted that this kind of alternatives require more development compared to the first group. It is also investigated in this study to what extend available alternative techniques to print the design onto the cloth are suitable from the applicant perspective.

Finally it is evaluated if relocation of part of the production could be a suitable alternative for the applicant.

Alternatives are listed in Table 3. An initial evaluation of these alternatives is done on the basis of:

- Technical feasibility
    - of the final product
    - of the process
- Economical feasibility
- Availability
- Overall reduction of risk

The alternatives, which are deemed to have potential, are further evaluated in chapter 4.

Table 3: List of alternatives

Alternative	Main argument for non-suitability
Different solvent for dissolving current resin from the cloth.	
a. solvents with no flash point. (eg Perchloroethylene) ALTERNATIVE 1.1	PERC is identified as non-flammable solvent with physical properties closest to TCE (1) PERC provides no overall reduction of risk. (2) High investment costs are needed and higher operational costs are foreseen. High-risk investment because of the uncertain regulatory status of PERC. (3) Technically the process is not yet available and cannot be made available prior to the Sunset Date. **This alternative is elaborated in § 4.1**

Alternative	Main argument for non-suitability
b. solvents with flash point < 55°C (eg: toluene, Ethyl acetate, acetone,) ALTERNATIVE 1.2	Toluene is identified as the flammable solvent with physical properties closest to TCE (1) Technical feasibility is not proven, (2) Industrial continuous or batch textile processing machines are not available due to explosion/fire risk (ATEX[v]). Development is still needed and will not be completed by Sunset Date. Permits for using flammable solvents on site not available, (3) Very high investment costs and higher operational costs, higher compared to alternatives based on non-flammable solvents. **This alternative is elaborated in § 4.2**
c. solvents with flash point > 55°C (dry cleaning solvents C10 and higher)	(1) Not technically feasible because no sufficient separation of resin and these solvents (high boiling), even under vacuum, hampering the reuse of the resin. (2) Economically not feasible: high operational costs because of the 100% loss of all resin. Raw material cost would increase with 27-30%. Additional costs for waste handling and additional costs for logistics for fresh and waste resin. **This alternative is not further analysed in detail.**
d. Supercritical CO_2	(1) Not technically feasible because resin only dissolves partly in this solvent **This alternative is not further analysed in detail.**
e. Industrial Soap	(1) Not technically feasible because in combination with resin this gives extreme pollution of the equipment. (2) No suitable machine available. Further extreme waste water pollution (eutrification) due to high resin and substance emissions to waste water. **This alternative is not further analysed in detail.**
f. Switchable solvents ALTERNATIVE 1.6	(1) Technical feasibility is not proven: no suitable solvent for resins has been identified in literature. However, these solvents have been proven for tar sand processes. These solvents have the potential to significantly reduce the Opex and carbon footprint of the process as a lower energy uses can be expected. Hence, the option has been included in the long-term R&D plan of this AfA. **This alternative is elaborated in § 4.6.**
<u>Different resist</u>	

[v] ATEX: ATmosphères EXplosive: regulation regarding the use of explosive substances (94/9/EG, 1999/92/EG)

Alternative	Main argument for non-suitability
a. Rosin, or chemical modified abietic acid ALTERNATIVE 1.3	(1) Technical feasibility is not proven: process for recovering of this resist still needs to be developed and will not be available by Sunset Date. (2) Higher discharge of unrecoverable rosin to waste water (environmental permit). Therefore increased operational costs due to high rosin losses This alternative is linked to the Alternative 1.4 for Use 2, developed in §4.4 in the AoA of Use 2 **This alternative is elaborated in § 4.3**
b. Paraffin as resist.	Technically not feasible because (1) resist cannot be printed with current equipment and (2) no bubbling possible ;(too low T_{glass}) gives different product look. **This alternative is not further analysed in detail.**
b. Acrylic acids as resist	Technically not feasible Resist required acidic environment which is not compatible with the alkaline dyes and fixation baths and with the cotton cloth. Cotton is affected in acid conditions. **This alternative is not further analysed in detail.**
c. Chemical Resist	Technically not feasible because (1) this does not work for all dyestuffs used by Vlisco, only for reactive dyes. (2) No bubbling possible, hence different product look. **This alternative is not further analysed in detail.**
Resin removal without solvent	
a. Mechanical rubbing or breaking and high pressure water spray ALTERNATIVE 1.4	Technically not feasible because insufficient removal of resin in the yarn **This alternative is elaborated in § 4.4**
b. Ultrasonic removal ALTERNATIVE 1.4	Technically not feasible because insufficient removal of resin in the yarn **This alternative is elaborated in § 4.4**
Direct printing of colours	
a. Rotary screen printing without using resist ALTERNATIVE 1.5	(1) Technically not feasible because different end product. Different product image and will not be considered as wax product by the market. (2) Marketing the different product is economically not feasible. **This alternative is elaborated in § 4.5**
b. Inkjet printing without using resist ALTERNATIVE 1.5	(1) Technically not feasible because different end product. Different product will not be considered as wax product by the market. Suitable inkjet printing equipment is not available **This alternative is elaborated in § 4.5**
Outsourcing dewaxing	

Alternative	Main argument for non-suitability
a. De-waxing with TCE outside of the EU, colour fitting at Vlisco	(1) Alternative is not available: no sufficient capacity for de-waxing is available and cannot be made available by Sunset Date. (2) Economically not feasible: Additional costs for sending fabric to de-waxing and back; logistic cost for returning of the resin. One time cost to lay off personnel after closure of local de-waxing. Long lead-time, due to transport is not acceptable in a fashion context. (3) No overall reduction of risk. **This alternative is not further analysed in detail.**
b. Relocate factory outside EU	(1) Alternative is not available and cannot be made available by Sunset Date. (2) Unsuitable because product is not "Real Dutch Wax" anymore. (3) Relocating the factory requires very high investment costs for the new factory. High cost to close the entire plant. (4) No overall reduction of risk. **This alternative is not further analysed in detail.**
c. De-waxing with PERC in Europe (not Helmond)	(1) Availability: There is not enough capacity available in the EU for textile cleaning with PERC. (2) Technically not feasible, available machines are not capable to handle and recover high loads of resin. (3) Operational costs increase. (4) No overall reduction of risk in the EU. (see § 4.1.4.) **This alternative is not further analysed in detail.**
d. De-waxing with solvents in industrial dry cleaning machines in Europe	(1) Availability There is not enough textile dry-cleaning capacity available in the EU (2) Technically not feasible, no recovery of resin possible and only batch equipment available. No dry cleaning machines available that can handle high loads of resin. (3) Operational costs increase raw material, replacement of resin environmental costs for discharging high amounts of solvent with resin. **This alternative is not further analysed in detail.**

3.2. Description of efforts made to identify possible alternatives

The applicant has a long-term and extensive history of R&D efforts, initially motivated by a desire to reduce the use of Volatile Organic Compounds. This resulted in a significant reduction of the usage of trichloroethylene as depicted in Figure 4. Table 4 gives an overview of the improvements made over time.

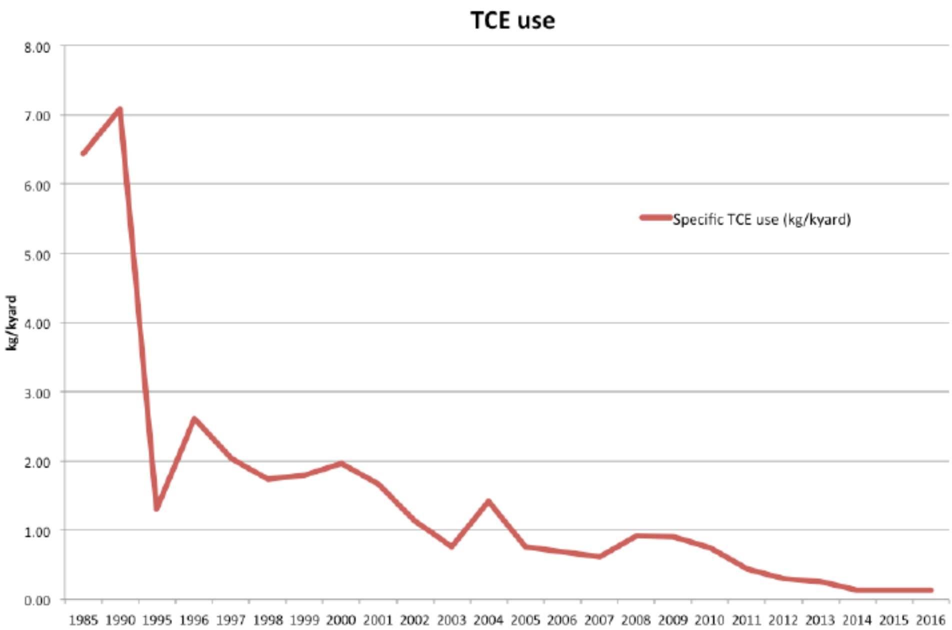
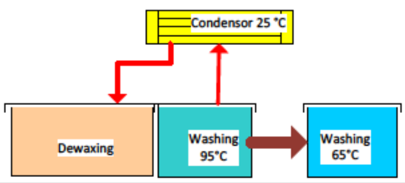
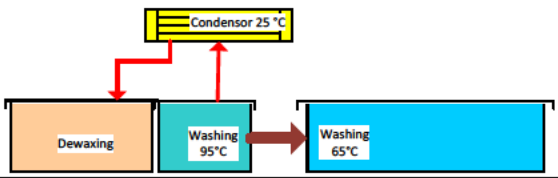
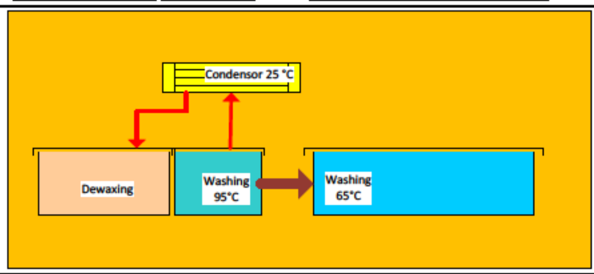
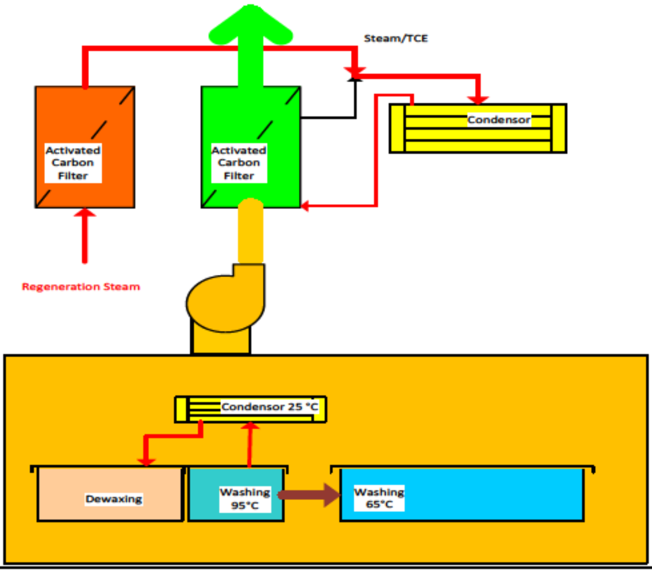
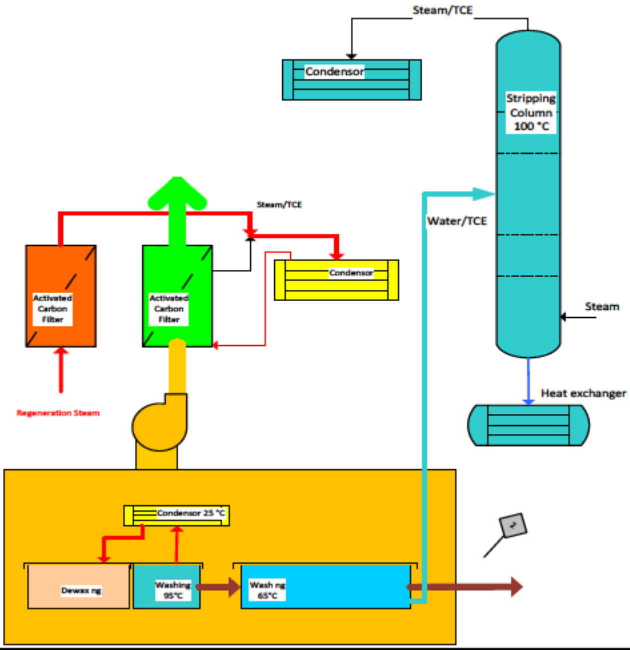
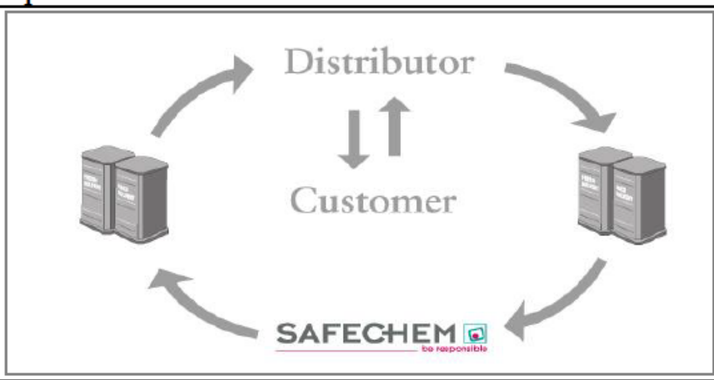


Figure 4: Reported TCE use per yard cloth produced; 2014-2016 are predicted values

Table 4: Process improvements for reduction of TCE emissions

1950: TCE condenser to recover TCE	
1985: Additional cloth washing	
1991: Enclosing de-waxing	

<table>
<tr><td>1991: Active carbon filter</td><td>
</td></tr>
<tr><td>1991: Steam stripping of waste water</td><td>
</td></tr>
<tr><td>1991-2013</td><td>Connecting all water streams to water stripper</td></tr>
<tr><td>2013:</td><td>Connecting vent to active carbon filter</td></tr>
<tr><td>2013:</td><td>Optimize resin distillation conditions</td></tr>
<tr><td>2013: Introduction of Safetainers</td><td>
</td></tr>
</table>

Apart from the intensive efforts to reduce TCE emissions, the applicant also made significant investments in research to eliminate TCE from the production process. The investigations started in the early 1980s. A relevant selection of the research documents that cover this effort is given in Appendix A. To limit the number of reports the emphasis is on the most recent research done from 1990 till present.

The R&D effort on the replacement of TCE as an extraction solvent, has to take into account the interaction of Use 1 with the use of TCE as a solvent to remove resin from a water stream (as described in Use 2 of the application dossier). Both uses are part of an integrated process within Vlisco and have certain equipment in common (eg equipment for the separation of TCE and resin). Since Use 1 is the driver in the Vlisco process and Use 2 is only a consequence of Use 1, it was recognized that a replacement was to be found for first for Use1.

Options for both uses have been investigated from 1985 onwards with limited positive success so far.

Ideally the applicant prefers a solvent free option or alternatively an environmentally friendlier and less hazardous (green) solvent. For Use 1 in combination with Use 2, the following solvent free options were investigated and were proven not to be technically feasible:

- RSP printing (= resin-free option for Use 1, eliminating also Use 2)
- Inkjet printing (= resin-free option for Use 1, eliminating also Use 2)

Other options that were investigated for Use 1 and were proven to be technically not possible:

- Mechanical de-waxing
- Industrial soaps

In respect of a green solvent, the applicant is in the early stages of research with a switchable solvent (see Alternative 5 in Section 4.6). Even though the research is very young, there is a high likelihood to success. Hence, switchable solvents are further described in the long-term development plan.

3.2.1. Research and development

Several routes of investigation have been followed over the past 25 years:

1. Different solvent for the removal of the resin from the cloth
2. Solvent free removal of the resin from the cloth
3. Different resist
4. Direct printing of image
5. Outsourcing
6. Switchable solvents

In the following sections, the results of these investigations are discussed.

1. Different solvent for the removal of resin from the cloth

To replace TCE, alternative solvents have been studied in the past, mostly because this option has potentially the lowest impact on the product properties and product look.
In the past ten years, alternative solvents have been investigated systematically for replacing TCE. Based on the solubility parameters several solvents could fulfil the function of TCE. However, besides the function of dissolving the wax, the alternative solvent also has to be removed from the cloth and both solvent and resin have to be separated and recovered for re-use, (see Appendix A, report 63.)
From discussions with research institutes, solvent suppliers, equipment manufacturers and starting with desks studies, a broad range of solvents have been selected for tests on laboratory scale. [redacted][11] Beside solubility, flammability is a property of the solvent of major importance. Flammable liquids have to be used in equipment which cannot be a source of ignition of the liquid. Specific regulations apply (ATEX).

Important selection criteria for potential alternative solvents that are inflammable are provided in Table 5:

Table 5: Selection criteria for non-flammable solvents[12]

Property	Criticality	Criteria
Speed of solubility for resin	defines equipment size and capacity	[redacted] of the solubility speed of TCE
Solubility of solvent in water	defines remaining concentration in waste water	[redacted]
Boiling point	defines the design and operational costs of recovery installation	[redacted]
Flashpoint	current installation is not suitable for flammable solvents	none
Density difference with water	defines separation of water solvent in the cloth extraction	[redacted]

Appendix B lists an overview from solvents with their main properties. All these solvents have been investigated for their potential as alternative for TCE.

From the non-flammable solvents the properties of Perchloroethylene (PERC) are closest to the required properties. But even PERC is not a drop-in alternative and requires extensive adaptations of the processes and equipment to control the huge losses of PERC. Tests on commercially available industrial batch and continuous machines have been done ([redacted])[13] See also section 4.1.2. .

Important selection criteria for potential alternative solvents that are flammable are provided in Table 6:

Table 6: Selection criteria for flammable solvents[14]

Property	Criticality	Criteria
Speed of solubility for resin	defines equipment size and capacity	[redacted] of the solubility speed of TCE
Solubility of solvent in water	defines remaining concentration in waste water	[redacted]
Boiling point	defines the design and operational costs of recovery installation	[redacted]
Flashpoint	current installation is not suitable for flammable solvents, modification to the equipment will be required	<55 °C
Density difference with water	defines separation of water solvent in the cloth extraction	[redacted]

The boiling point of several solvents listed in Appendix B is too high. It is impossible to separate such a solvent from the resin by distillation, even under vacuum without affecting the properties of the resin. The distillation temperature is too high and thus degradation of resin occurs.

[redacted][15]

2. Solvent free removal of the resist from the cloth

A lot of effort on laboratory, pilot and full scale has been made to remove the resin from the cloth without using a solvent. Detailed documentation of this research is given in Appendix A, report nrs: 72, 91, 108, 109. (see Appendix A). Two alternative techniques were tested for mechanical removal of the resin from the cloth:

- Mechanical: [redacted]
- Ultrasound: [redacted]

[redacted]

[redacted]

[redacted]

- [redacted].[16]

3. Different resist

Materials like paraffin’s, silicates, starches, acrylic acids, chemical resists were investigated as an alternative to the current synthetic hydrocarbon resin. None of these materials could:

- withstand the dyeing processes
- create the correct product look
- be removed without affecting the cotton cloth or dye

The only alternative resist that provided a final product close to the current product look is crude or modified rosin. This resist has a good “melting” range (correct viscosity), is very sticky [redacted][17] These bubbles are created during the breaking-off process (see Figure 2). The temperature during the breaking-off process is defined by the temperature of the water used (max. 25°C summer [redacted][18]. The difference between this resist and synthetic resin is the chemical reactivity. Such a resist can chemically react in the presence of alkali whereas the synthetic resins are chemically inert. This resist turns into a water soluble material and can be washed out with water, offering the possibility of de-waxing without using organic solvents. The relevant research on alternative resists is described in report nrs :53, 103, 104, 105, 107 (Appendix A). Further research is required to handle the chemical reactivity of this resist.

4. Direct printing of image

Vlisco has extensively researched printing techniques such as screen-printing and inkjet printing. These techniques cannot yield the same product look. This issue has never been solved to satisfaction even after extensive testing. The reports that describe this research are given in documents 87, 98, 99, a2 (see Appendix A). In the following sections details are provided.

1. **Screen printing by Rotary Screen Printing (RSP) or Flatbed Screen Printing (FSP):**
   [redacted][19]
   (3) with regard to the colours, Indigo is of high importance to the African market. It has been used in African cloth-making since the 16th century. Indigo is currently not possible to print on an industrial scale with RSP in the required quality.

2. **Inkjet printing**
   The following companies providing inkjet technology have been contacted over the last years: [redacted][20]

Company	Nature of investigation
[redacted]	Site visit with tests on the site of the supplier [redacted]
[redacted]	Site visit, [redacted]
[redacted]	Extensive contacts, [redacted]
[redacted]	Extensive testing done; company went out of business
[redacted][21]	Contacts were made during fairs, no tests done, technology was not suitable

The conclusions from these projects were:

[redacted][22]

5. Outsourcing

Outsourcing wax removal with TCE outside EU does not reduce the risks of working with TCE; only the risks are replaced to other locations. In addition, it leads to extra operational costs and transport. [redacted]

[redacted][23]

6. Switchable solvents

Switchable solvents[vi] is a technology by which the solubility characteristics of the solvent system can be reversibly manipulated (the so called “switch”). This is done via the introduction or removal of carbon dioxide. In the absence of CO_2 the switchable solvent behaves like a traditional, low polarity, organic solvent. On exposure to CO_2 and in the presence of water, the solvent becomes hydrophilic and water miscible. Removal of the CO_2 from the system causes the switchable solvent to revert to its hydrophobic form that is again immiscible with water.

Professor Dr. Philip.G. Jessop from Queen’s University Canada developed this technology in collaboration with The GreenCentre Canada[vii]. This breakthrough discovery of CO_2-triggered switchable solvents was listed in the Canadian Chemical News trade journal as one of the twenty key chemical discoveries in Canada of the last 100 years. In 2012, Professor P.G. Jessop was awarded with the Canadian Green Chemistry & engineering Award and in 2013 he won the ENI-award[viii] for his CO_2-triggered control of oil/water mixtures.

[vi] http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-$5.48-million.php

[vii] http://www.chem.queensu.ca/people/faculty/jessop/switchable.html

[viii] http://www.eni.com/eni-award/eng/vincitore_2013_philip_jessop.shtml

In Appendix F, more details are provided on this technology.

A major advantage of this technology is the reduction of energy consumption, as there is no need for evaporation anymore to separate the solvent from the resin.

As mentioned, the applicant has a long-term track record of research of alternative solutions to TCE. Until now this has resulted in elimination of alternatives that have been proven by the research not to be technically feasible. Hence, this new technology of switchable solvents is in the very early stage of investigation. However, seen the similarity to the current process technology – i.e. extraction of the resin – the chance that the product image (look & feel) will be similar, is very likely. Therefore, this new technology has been identified by the applicant as a technology of very high potential.

To develop this technology, contact has been made with GreenCentre Canada and Switchable Solutions Inc[ix]. Discussions are ongoing to initiate projects in line with the 12-year development plan as documented in 4.6.2.1

3.2.2. Data searches

All available reports within Vlisco concerning the replacement of TCE, have been reviewed recently (2013) by an external engineering company (Appendix A: Overview knowledge documents TCE elimination: document 3a). This review had as objective to revisit old investigations in the light of more recent knowledge. This was done based on the internal engineering knowledge of that company and by consultations with external specialists.

See also Appendix E: Consulted data sources.

3.2.3. Consultations

Several solvent suppliers, research institutes and equipment manufacturers have been consulted over the past years. These consultations have a.o. provided a list of candidate solvents for replacement of TCE and merit further investigation.
In 2004 an expert panel was consulted on the possibilities to develop a TCE-free de-waxing process. The experts consulted were from industry and universities in the fields of solvents, separation processes or washing processes. The conclusions are reported in documents 53, 90 in Appendix A.

Also industrial companies were consulted on finding alternatives

[redacted]

[redacted]

[ix] http://www.switchablesolutions.com/

- [redacted][24]

On the topic of switchable solvents, GreenCentre Canada and Switchable Solutions inc. has been contacted.

The conclusions from these consultations were used as input for the research efforts described above.

4. SUITABILITY AND AVAILABILITY OF POSSIBLE ALTERNATIVES

The six alternatives with the highest likelihood for success will be described in detail in the following chapters.

ALTERNATIVE 1.1: Different non-flammable solvent for dissolving current resin from the cloth, (Perchloroethylene)
ALTERNATIVE 1.2: Flammable solvent for dissolving current resin from the cloth (Toluene)
ALTERNATIVE 1.3: Different resist, rosin or modified rosin which are “saponifiable” in presence of alkali.
ALTERNATIVE 1.4: Resin removal without solvent
ALTERNATIVE 1.5: Direct printing of the image
ALTERNATIVE 1.6: Switchable solvents

In this section, each alternative is evaluated in terms of its technical feasibility, economic feasibility, potential for risk reduction, and availability. An overall assessment of suitability is then provided. The identification of the option which Vlisco will adopt if it is no longer able to use TCE after its Sunset Date (the ‘non-use scenario’) can only be undertaken in combination with the appraisal of options for Use 2, due to their technical and economic interdependence. This is on the basis of quantitative cost modeling and qualitative considerations at the end of the section.

In the evaluation of any of these alternatives, the history and the current state of the equipment is relevant. The current TCE based de-waxing installation is well maintained and not due for major replacement and not obsolete in any way. The recovery level for TCE and resin of the installation is high, at 99.99 % and 95% respectively.

Current de-waxing technology dates from 1950. The extraction technology has not changed since. Additions have been made to improve the TCE use and reduce the exposure over the period 1985-2014 (see Table 4).

The de-waxing installation uses the same technology now as in 1950. In the last five years major investments were undertaken in other parts of the plant to increase the overall capacity of the plant. No investments were required at the level of the de-waxing or resin recovery operations except for the installation of computer control of the resin recovery area and de-waxing area.

In 2010 the first de-waxing machine (taken into service 1985-1988) was replaced with similar de-waxing technology. The oldest current de-waxing machine is about 30 years old but still in perfect operational condition. There are no intentions to replace the equipment nor is a major overhaul foreseen.

4.1. ALTERNATIVE 1.1: different non-flammable solvent (PERC)

Current solvent TCE is not flammable. Alternative 1.1 considers other non-flammable solvents which can fulfil the function of TCE. From the investigated solvents, mentioned in the list attached in Appendix B, perchloroethylene (PERC) has been identified as a potential alternative both for Use 1 and 2. In this case, PERC would be a direct functional replacement for TCE as a solvent for the resin.

4.1.1. Substance ID and properties

Several solvents are evaluated for dissolving the resin from the cloth. They are mentioned in the research part and in Appendix B. For each of the solvents the five relevant properties are mentioned:

Table 7 Relevant properties of solvents which can be used to extract resin from cloth[25]

Property	Criteria
Speed of solubility for resin	[redacted] compared to TCE
Solubility of solvent in water	[redacted]
Flammability	Flashpoint : none
Boiling point	[redacted]
Density compared to water	[redacted]

PERC has been identified as the substance with technical functionality closest to TCE. This is based on recent intensive research on alternative non-flammable solvents (document 3a, Appendix A).

Table 8 Properties of PERC

IUPAC name: Tetrachloroethene Other names: Perchloroethene; Perchloroethylene; PERC; PCE	
Identifiers	
CAS number	127-18-4
EC number	204-825-9
Properties	
Molecular formula	C_2Cl_4
Molar mass	165.83 g mol^{-1}
Density	1.622 g/cm^3
Melting point	-19 °C
Boiling point	121.1 °C
Solubility in water	0.015 g/100 mL (20 °C)
Hazards	
Harmonized: Carc. 2 Aquatic Chronic 2	 H351 H411
Self classification: Skin Irrit 2 Skin Sens 1B STOT Single Exp 3	H315 H317 H336
Other	YES 9ii (R51)

IUPAC name: Tetrachloroethene Other names: Perchloroethene; Perchloroethylene; PERC; PCE	
Seveso	
ATEX	Not flammable
REACH status	
Substance is registered	
Included in CoRAP	Suspected Carc 1B Suspected PBT
Other Listings	
EU EDC EPA	

4.1.2. Technical feasibility

In Appendix B both pure and mixtures of solvents are listed. Some mixtures of solvents such as Vertel and Novec fulfil the criteria in Table 7. Use 1 contains a recovery process with a distillation and re-use of the solvent. Within such a process, the composition of a mixture does not stay constant. A changing composition of the solvent used in the process has an effect on the dissolving of the resin, which cannot be compensated for by changing process settings. Hence, mixtures of solvents are not taken into consideration as alternative for TCE. In this evaluation, only pure substances are considered. As mentioned above, PERC is non-flammable solvent with physical properties closest to those of TCE. The assessment made for PERC is to a large extent also applicable for the other non-flammable solvents, but the effects described below will be more pronounced.

It should be technically possible to change to perchloroethylene (PERC) in the resin removal process. However, there are a number of differences with TCE that lead to difficulties that cannot be disregarded:

- **Removal of resin from cloth:** The speed of dissolving resin in PERC is [redacted][26] lower than in TCE; this increases the required residence time for the resin removal process. To achieve this higher residence time, either the throughput has to be reduced or the **equipment needs to be replaced** with different and additional equipment. In the case, the equipment would not be replaced; the de-waxing capacity would be reduced. Recent investments have brought the capacity of the rest of the plant in line with the installed de-waxing capacity. This means that any reduction of the de-waxing capacity will lead to a reduction of the overall capacity of the site and render the recent capacity investment useless.

  Commercially available equipment for the de-waxing with PERC has been evaluated (3 suppliers) during tests at the suppliers' facilities. All commercially available equipment has a smaller capacity and is designed for textile cleaning with a typical load of dirt of 1% of the fabric weight. The resin to be removed in the process of the applicant is up to 30% of the weight of the fabric. [redacted].[27] The commercial equipment for textile cleaning with PERC is optimized for wool and polyester and not for the treatment of cotton cloth. It is unclear to what extend this will be a problem.

Beside the fact that the batch equipment was less effective, operating batch ([redacted])[28] equipment requires significantly more personnel (1 to 2 FTE per shift per machine) and requires cutting the cloth in smaller parts fit for the batch equipment.

For all machines both batch and continuous, the cloth could only be de-waxed to an acceptable level at much lower production rates. Additional development is needed to achieve current and future production rates.

- **PERC concentration in cloth leaving the de-waxing unit:** For reasons of exposure minimization, it is important that the solvent is maximally captured and recovered from the cloth leaving the de-waxing unit. This is in the current installation of the applicant more difficult with PERC compared to TCE. Due to the low boiling, TCE evaporates from the cloth quickly after the de-waxing unit at a confined location where local measures can be taken (LEV). In case of a solvent with a lower vapour pressure or higher boiling point, the evaporation will be slower and more spread out over the production site. This means that even with a same concentration leaving the de-waxing unit, the exposure to PERC will be higher compared to TCE.

  The current rinsing step will not be sufficient to assure a same concentration of PERC at the exit of the de-waxing unit as now for TCE. Currently the temperature of the first water bath after the extraction stage is 95°C, above the boiling temperature of the TCE. This provides a significant driving force to evaporate the solvent. With PERC this is not longer possible; the boiling point of PERC is above 100°C. An alternative process will have to be developed and built to achieve a sufficiently low concentration of solvent in the cloth.

  In summary, the use of PERC in the current de-waxing installation will lead to a higher solvent concentration in the cloth leaving the de-waxing. The remaining solvent in the cloth is expected to evaporate from the cloth slowly throughout the production site, potentially exposing all workers downstream from the de-waxing to PERC.

- **Resin-Solvent separation:** Separation of the resin from the solvent will be more difficult due to the approx. 30°C higher boiling point of PERC (PERC T_{boil} = 121°C; TCE T_{boil} = 87°C). High concentration of solvent in the resin cannot be accepted for quality reasons in the dyeing process (influence on T_{glass} of the resin) and, more importantly, to avoid exposure of workers to PERC in the dyeing process. To achieve a similarly low level of solvent in the resin as with TCE, a higher temperature will be needed in the current (steam) distillation to separate the resin from the solvent. This will lead to an additional thermal degradation of the resin resulting in a change of viscosity and glass transition temperature of the resin. The longer stripping time and higher temperature are not desired.

  A comparable laboratory-scale steam-stripping test has been carried out with a TCE and PERC extract (resin – solvent mixture). See Figure 5. Data are normalized for strip steam amounts for 1 kg wax. It can be seen that the PERC-laboratory stripping (green line) is less effective compared to TCE-laboratory stripping (purple line). With 800 kg stripping steam per 1,000 kg printable wax, TCE levels of 0.00008 kg/kg wax are normally realized. With the same stripping conditions, the remaining solvent concentration in PERC extract would be around 0.0007 kg/kg wax. In other words, using the same stripping conditions as now the PERC in the resin would be a factor 9 higher than with the TCE.

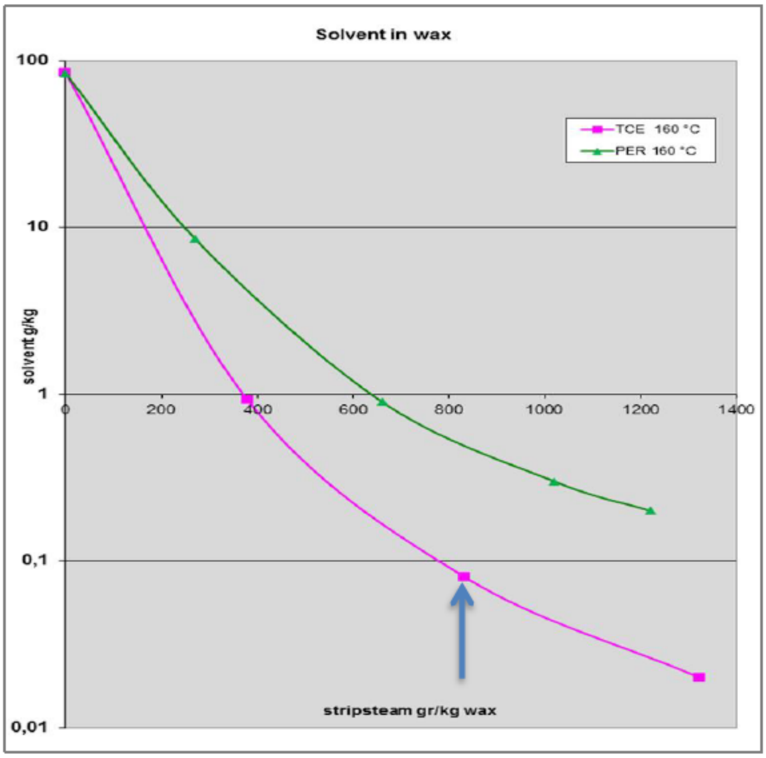


Figure 5: Solvent concentration in the resin after stripping

In case we take into account the factor 9 of extra PERC in the resin, the consequences of a higher PERC concentration in the resin are:

- PERC released from the resin during resin printing and during all subsequent processes could lead to exposure of workers. In total 6.3 mio kg resin are printed on cloth every year. This means a potential diffuse source of an additional (4,400 kg) of PERC would be created in the factory.
- An increased PERC concentration in the resin, also leads to an additional PERC emission to wastewater. Although Vlisco undertakes wastewater treatment (effectiveness of appr. 90%) to remove resin from waste water, every year approximately 60,000 kg of resin are discharged in waste water. This means possibly an additional 42 kg PERC per year would be released in the wastewater via resin.

It must be remembered that these calculations are assuming that a PERC-based alternative for Use 1 and Use 2. In case a solvent free alternative is chosen for Use 2, the additional emission of PERC via water and air will be lower.

- **Water-Solvent separation (see also Use 2):** The current steam-stripping process for the removal of the solvent from the water operates at 100°C, which is above the boiling point of TCE but below the boiling point of PERC. As a result, higher concentrations of solvent are expected in the water with the current water-stripping installation. An alternative process will have to be developed and installed, to achieve a sufficiently low - in accordance to the requirements of a new permit - concentration of solvent in the wastewater (shared with Use 2).

Conclusion:

1. To introduce PERC as an alternative to TCE, a major redesign of the current installation is needed. The de-waxing unit needs a complete new design to provide sufficient residence time for dissolving the resin and to allow the removal of the solvent from the cloth. Even so, additional pre-treatment will be required to reduce the resin load to the PERC dissolvers. Resin-solvent and solvent-water separation units will have to be replaced by other process equipment based on a different technology, to allow a sufficient separation between the components, taking into account the higher boiling point of the solvent and the thermal stability of the resin. A development and construction time of three to four years is to be taken into account for such a major redesign even when starting with commercially available equipment.

2. The technical feasibility of the replacement of TCE by PERC for Use 1 is not yet proven. The extraction of the resin from the cotton cloth and the use of PERC in the recovery step, is based on known technology. The current installation is, however, not suitable for the use of PERC because of the different properties of PERC. The replacement of TCE by PERC as a solvent for removal of resin from the cloth still requires significant development time. Although some trials have already been done, the different physical properties of PERC lead to process changes that need to be tested and developed first. A development and implementation time of three to four years is expected.

3. Other non-flammable solvents are available but their physical properties are less similar to TCE than PERC. For none of these solvents, has the technical feasibility to be used in this process has been proven. The development of processes based on these solvents is at least three years behind the current state of process development for PERC. For each of these solvents dissolving trials need to be done and the interaction with the cloth or dyes needs to be investigated.

4.1.3. Economic feasibility

The following additional costs, associated with the implementation of this alternative are considered:

- Capital cost
- Operational cost
- Costs associated with downtime

Costs associated with the remaining book value of the equipment, which is replaced, is not taken into account.

The following assumptions and parameters are adopted:

- Base period for calculating PV is 2016, calculated over the period 2016-2034. – This is longer than the period used for appraisal in the SEA, which is based on the decision horizon for authorisation decisions, and better reflects Vlisco's investment cycle in relation to these types of investments
- Discount rate is 10% - This is higher than the 4% discount rate mentioned in the ECHA SEA guidance, which is used in the SEA for this application, and reflects the higher cost of capital faced in the commercial sector compared with the societal perspective adopted in the SEA

- Constant fabric production volume over the assessment period; same as for 2014 (27 mio yards)

4.1.3.1 Capital cost

As set out in section 4.1.2. this alternative will require the following main investments:

- Replacement of current de-waxing equipment
- Additional pre-treatment
- Modifications to resin distillation tower and water stripper

The investments costs were estimated based on budget prices for main equipment, standard engineering cost estimation for minor equipment and taking into account an installation factor (to cover insulation piping, instrumentation, and so on). This project estimate is made as part of the pre-engineering project for this alternative. All project timelines and project costs are estimated using standard assumptions regarding project costs and timelines and not considered as a rush project.

Details are provided in the Table 9 below:

Table 9: Breakdown of investment costs of Alternative 1.1[29]

Type of cost	**Description**	**Cost estimate (€million)**
Testing	Including overhead costs	[redacted]
Pre-treatment	Cost of equipment and installation. [redacted]	[redacted]
PERC de-waxing	Cost of equipment and installation.	[redacted]
Recovery of PERC and wax	Cost of new equipment and installing updated recovery system (e.g. updating stripping tower and distillation units).	[redacted]
Contingency	This is ~10% of the budget mentioned in the sub-projects, for unknown expenses that may arise. It is good practice to avoid "optimism bias" by allowing contingency for unspecified risks[x].	[redacted]
Engineering and Project management	Vlisco are not able to internally manage a project this size Estimated Engineering and project management is 20% of equipment and installation cost	[redacted]

[x] HM Treasury (2003) - THE GREEN BOOK Appraisal and Evaluation in Central Government - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

Type of cost	Description	Cost estimate (€million)
Pre-engineering cost	4% of the estimated budget is spent on the project prior to authorisation decision to reduce the project lead-time.	[redacted]
Total		[redacted]
	PV	[redacted]

There is no installation available today at Vlisco to handle PERC. Such an installation still needs to be designed and installed. It was estimated that this would take about 3 to 4 years. Because this alternative is part of the non-use scenario of Vlisco, Vlisco has initiated a pre-engineering project to prepare for its implementation, as a means to managing the regulatory risk associated with the entry of TCE into Annex XIV for this alternative. This should reduce the project lead-time from four years to 2.5 years following any decision of non-authorisation. The costs of this pre-engineering are estimated to 4% of the total project and are subtracted from the total project cost (see Table 9). This effort is only made for the non-use scenario for Use 1. Vlisco considers this as a measure to reduce business risks. Reducing the project time for this alternative has the highest impact on the cost of the non-use scenario. The costs of the pre-engineering are significantly lower compared with the costs associated with the loss of production and sales in case of a longer project lead-time. They are low enough to be an appropriate way to manage business and regulatory risks, even if (as is demonstrated in the SEA) there is a clear case for use of TCE to be able to continue via authorization.

If this alternative was to be adopted under a non-use scenario, wax fabric production at Vlisco would have to cease temporarily (see below), meaning that there could be a certain contribution of the Vlisco staff to the construction of the installation. This could lead to a certain level of double counting of costs: labour costs in the construction project and staff wages during shutdown of wax production. This will have only a limited effect as the Vlisco technical staff is small and is mainly a maintenance staff not trained or experienced in construction work

The estimated investment cost for this alternative has been estimated at [redacted][31] € (PV [redacted] €)[32] based on the assumption that commercially available equipment can be used without need for equipment development.

Because of the uncertain regulatory status of PERC (see section 4.1.4), the investment in a PERC-based installation is considered a high-risk investment. The investment is not considered environmentally sustainable, as the alternative does not represent a sustainable reduction of the risk.

4.1.3.2 Operational cost

Commercially available PERC based equipment cannot be integrated as well into the existing installation as the current de- waxing unit. The feed of the cloth into the de-waxing stage and the out-feed of the cloth to the next installation are fully automated in the current installation.

Investigations and discussions with the suppliers have indicated that he capacity of the PERC based machines is less compared to the current installation. While currently 2 machines are in operation for de-waxing, in case of PERC, at least four machines will be required.

The additional machines and the reduced integration result in estimation of an additional manpower of 16 FTE. It needs to be noticed that this department of Vlisco works full continuously in shifts.

The yearly additional cost of these workers is estimated to be [redacted][33]. The NPV for the period 2016-2034 is [redacted] €[34]

4.1.3.3 Downtime Costs

Implementing this project in the non-use scenario will require at least a 2-year period after the sunset date where wax prints (and ready to wear clothes made with wax prints) cannot be made as they are dependent on the use of TCE. This is assuming that the decision for authorization is six months prior to the Sunset Date. Following a decision of non-authorisation, Vlisco would continue the engineering project for the installation of this alternative. The construction work is limited to 2.5 years after the date of EC decision (expected December 2015; or 2 years after the Sunset Date – April 2016) .In the period between Sunset Date and completion of the project, Vlisco would not be able to produce any wax-based product resulting in a significant loss of sales in that period.

During this two-year period, there would be some reduction of the headcount at Vlisco. The main reduction would be caused by the termination of the contracts with temporary personnel. This accounts for a yearly cost of [redacted] €[35].

The average age of the Vlisco production personnel is quite high, which means that making staff redundant would be expensive. But even more importantly, there would be an enormous amount experience lost if experienced, permanent staff are released. This is especially the kind of experience the company would need at the start-up of a new and changed process after a period of closure. Starting up a process without experienced people would be extremely difficult, and subject to delays and additional costs. Early hiring of staff so that they can be trained could partly compensate for this but at great expense. However, when the period of closure is likely to be relatively short, the savings in staff wages that can be realized from making staff redundant become marginal compared with the additional costs of rehiring and training, and the risk of having a lack of experience during start-up increases. As a result, Vlisco has decided to maintain its headcount of permanent staff during this two-year period. A 5% reduction by natural retirement (after 2 years) can be assumed but is not taken into account in the calculations, as this would occur anyway.

During the temporary closure of wax fabric manufacturing, the total site energy cost and the raw materials cost would be reduced to the costs for the production of Java product. At least a 96% reduction of the energy cost could be expected. (total energy cost is [redacted] €[36]). This represents a yearly cost reduction of [redacted] €[37] for energy. The calculation of the cost saving due to the reduced use of raw materials is presented in Table 10.

During the temporary suspension of wax-production, the raw materials cost associated with the wax productions would not be incurred. According to McKinsey (2014), Vlisco (Helmond site) made direct operating profit of [redacted][38] in 2012, which represents [redacted][39] compared to sales revenue of €[redacted] [40]for 2012. However, sales for 2012 were slightly higher than those used by McKinsey; €[redacted][41] (See Section 2.3 of the SEA which includes sales of non-wax products too), but conservatively assuming direct operating profit is still the same [redacted][42]), profits represents [redacted][43] compared to sales revenue. Based on this split, Table 10 provides a breakdown of estimated sales revenue for 2014

Table 10: Available breakdown of Vlisco Sales revenue (2014)[44]

	Value (€ million)	%
Cost of raw materials (see SEA section 2.6)	[redacted]	[redacted]
Profit	[redacted]	[redacted]
All other components (e.g. production, labour and investment, energy)	[redacted]	[redacted]
Total sales	[redacted]	100%

The costs of the downtime during which no-wax product can be sold, is estimated starting from the lost revenue during this period corrected for the total avoided costs (wage, raw materials, energy) directly related with the wax production:

Table 11: Lost sales revenue[45]

Products made by Vlisco	Lost sales revenue (€ million)				
	2016 (6 months)	2017	2018 (6 months)	Total	Total (PV)
Wax Print	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Wax Block	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Super-Wax	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 12: Cost of downtime for Alternative 1.1[46]

PERC for Use 1	(€ million)				
	2016 (6 months)	2017	2018 (6 months)	Total	Total (PV)
Lost revenue	[redacted]	[redacted]	[redacted]	[redacted]	
Total avoided costs	[redacted]	[redacted]	[redacted]	[redacted]	
Downtime Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes:

1. Figures have been rounded to nearest whole number to avoid false accuracy

Table 12 sets out the estimated loss to Vlisco over this period (mid 2016 to mid 2018) at [redacted][47] million (PV). These figures are optimistic for several reasons:

1. It assumes there are no delays in the 2.5 year period, as of EU decision, needed for construction and testing of production lines. It is possible there can be unforeseen delays with equipment suppliers, availability of construction workers/management, weather, product testing and so forth.

2. It assumes following pilot testing and R&D that there is no unintended loss in wax print quality due to using PERC rather than TCE.

3. It assumes that once built, the new production lines will be fully operational (e.g. <85% operating capacity) from April 2018. In reality it may take another six months to a year (i.e. by April 2019) to optimise the production process before the lines to be operating at close to full capacity.

4. It assumes that Java production that is not dependent on using TCE can be fully operational whilst there are on-going construction works to build new production lines. Java prints are made using different technology (and on separate production lines) so may be less affected but in practice it might not be possible for health and safety reasons to have production staff working whilst there is construction work to retrofit the wax print production lines.

5. It assumes that demand (Vlisco's market share) will automatically return to those set out in the applied for use scenario (see SEA) once the new production lines are fully operational. As set out in Section 2.2 of the SEA, the African prints market is competitive and the competition is improving in terms of quality of their products. An absence of Vlisco wax prints for 2 years could lead to a reduction in demand due to reduced brand awareness, reputation and loyalty.

In theory Vlisco could seek to offset any lost sales by producing more Java prints. As noted above, this is unlikely to be possible in practice, given there will be shut down time required for building new production lines at the existing Helmond site. Whilst Java uses a different technology and separate production line it is within the same production building as the de-waxing process and therefore is also likely to be occasionally affected for health and safety reasons. Therefore rather than assuming an increase in production, the analysis is already optimistic in assuming no loss in production of Java prints.

There is a certain potential to further reduce the cost of the two-year period of no production of wax product by increasing production prior to the shutdown and built stock. This is only relevant for the traditional designs, not for the fashion driven designs. If this measure was taken during the 4-month period between EU decision on authorisation and Sunset Date, it is estimated that at most an additional 5% of a year capacity could be put in stock. This effect is not further taken into account in the calculations.

The main driver of the impact of the cost of this alternative is the length of the shutdown. As mentioned in section 4.1.3.1, all projects in this AoA have been estimated using standard assumptions for time and costs of engineering projects. In case of non-authorisation, it might be expected that the applicant will be tempted to shorten the project timeline by increasing the project budget. The effect of such a measure is highly dependent on the actual situation eg the order portfolio of main equipment manufactures and is impossible to estimate on beforehand with any level of accuracy.

4.1.3.4 Conclusion on economic feasibility of Alternative 1.1

Table 16 summarizes the preceding discussion and presents the estimated costs of implementing the PERC alternative for Use 1. The total present value cost over the period 2016-2034 is estimated to be around [redacted][48] (discounted at 10%). The largest proportion of this cost is the estimated loss during the implementation period. There will also be a permanent increase in operating costs. There are also negative qualitative impacts, such as the risk associated with the possible future regulation of PERC (see section 4.1.4.).

The conclusion is that the alternative to switch to PERC for Use 1 is currently not economically feasible.

Table 13: Overview costs Alternative 1.1[49]

Different non-flammable solvent for dissolving current resin from the cloth: Perchloroethylene		
Implementation time	2.5 years	- New PERC based de-waxing equipment - Modification of resin-solvent separation - No wax production, during implementation
Investment cost (PV)	[redacted]	- New equipment and installation of equipment
Impact on OPEX (PV)	[redacted]	- 16 additional FTE in period 2018-2034
Transition cost (PV)	[redacted]	- No production of wax product during 2 years - Loss of profit
Total (PV)	[redacted]	

4.1.4. Risk reduction potential

Of the solvents listed in appendix B, only 1,1,1-Trichoroethane and PERC fulfill the criteria mentioned in Table 7. 1,1,1-Trichloroethane was disregarded on the basis of its ozone depleting properties (Montreal Protocol, Annex B of controlled substances[xi]). Therefore, only PERC will be further considered in this section.

The key properties of PERC are listed in section 4.1.1. The assessment in this paragraph is based on
(1) a comparison of the hazard profiles of PERC and TCE;
(2) evaluation of PERC as possible SVHC;
(3) lack of regulatory framework to assess the risk of PERC;
(4) considerations regarding exposure to PERC compared to the current exposure to TCE,
(5) national legislations dealing with the use of PERC.

[xi] http://ozone.unep.org/new_site/en/Treaties/treaties_decisions-hb.php?art_id=59,60,61,62,63

1. Comparison of the hazard profiles of PERC and TCE

The hazard properties of PERC and TCE, based on their classification and other hazard information are compared in Table 14

Table 14: Hazard properties of PERC and TCE

	TCE	PERC	Comparison
Human Health hazards	Skin Irrit. 2 (H315)*	Skin Irrit. 2 (H315)	**No difference**
	Eye Irrit. 2 (H319)*	Eye Irrit. 2 (H319)	**No difference**
	Skin sens. 1B (H317)*	Skin sens. 1B (H317)	**No difference**
	Muta. 2 (H341)*		**PERC better**
	Carc. 1B (H350)*	Carc. 2 (H351)*	**PERC marginally better**
	STOT SE 3 (H336)* (central nervous system; inhalation)	STOT SE 3 (H336) (central nervous system; inhalation)	**No difference**
Environmental hazards	Aquatic Chronic 3 (H412)*	Aquatic Chronic 2 (H411) (harmonized)	**PERC worse**
Subject to Seveso Directive	No	Yes (cat 7B flammable liquid)	**PERC worse**
SVHC	Yes	Yes (Art. 57.f)? ***	**No difference**
in Candidate List	Yes	No	
CoRAP	No	Human health/CMR; Environment/Suspected PBT; Exposure/Wide dispersive use; Aggregated tonnage	**Depends on outcome substance evaluation**
PBT or vPvB	Not PBT Not vPvB	Included in CoRAP for suspected PBT properties	**Depends on outcome substance evaluation**
Endocrine Disrupting Properties	Not included in EU EDC list	Cat 2 (EU EDC list)	**PERC worse**
Effects on nervous system	Association with increased risk of Parkinson's disease**	Association with increased risk of Parkinson's disease**	**No difference**

* relates to endpoints with a harmonized classification

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*** PERC as EDC, Cat 2 according to EU COM dbase[xii]

[xii] http://ec.europa.eu/environment/chemicals/endocrine/strategy/substances_en.htm#priority_list

The main difference between both substances relates to:

- TCE classified as Carc 1B (harmonised classification) while PERC has a harmonised classification as Carc. 2. The CMR properties of PERC are under investigation (Substance Evaluation by Latvia),
- PERC is under investigation for its PBT properties (Substance Evaluation by Latvia) whereas TCE is considered not to be PBT,
- PERC has been included in the EU EDC database which is not the case for TCE
- PERC is more hazardous to the aquatic environment
- PERC is subject to the Seveso Directive, while TCE is not

2. Evaluation of PERC as a possible SVHC

It is currently unclear whether PERC fulfils the "SVHC" criteria listed in Art. 57 of REACH. However, there are indications that PERC could be considered a SVHC:

a) PERC is considered EDC, Cat 2 (EU COM dbase)
b) Substance evaluation by Latvia for PBT and CMR properties
c) Analogy between metabolic processes for PERC and TCE
d) Classification of PERC for sensitizing properties

a) PERC: suspected endocrine disruptor

Non-EU:
Perchloroethylene is a suspected endocrine disruptor (ED). Based on the description in CERI-NITE Hazard Assessment No.65 (2005), ATSDR (1997)[xiii] and NICNAS (2001)[xiv] adverse effects are observed in the embryonic development of rats and mice. Furthermore, PERC is able to transport across the placenta to the fetuses of pregnant women who have been highly exposed. PERC has been found in breast milk.
Since March 2013, PERC has been listed in the second list of the US-EPA endocrine screening program (EDSP) for chemicals for Tier 1 screening, meaning that PERC is going to be evaluated specifically for its endocrine disrupting properties (US-EPA, 2013)[xv].

Europe:

- Perchloroethylene is listed on the EU database for endocrine disrupting compounds[xvi] as a Category 2 endocrine disruptor, meaning that there is evidence of potential to cause endocrine disruption for human endpoints (Aggazotti, G. et al., 1994)[xvii].

[xiii] ATSDR (1997). Toxicological profile for tetrachloroethylene (Update). U.S. Department of Health and Human Services, Agency for Toxic substances and Disease Registry.

[xiv] NICNAS (2001). Tetrachlorethylene – Priority Existing Chemical assessment report No. 15

[xv] USEPA (2013). Endocrine Disruptor Screening Program; Revised Second List of Chemicals for Tier 1 Screening; EPA ICR No. 2488.01; Attachment G], March 29, 2013.

[xvi] EU ED database: http://ec.europa.eu/environment /endocrine/strategy/short_en.htm)

[xvii] Aggazotti, G. et al. (1994). Occupational and environmental exposure to perchloroethylene (PCE) in dry cleaners and their families. Archives of Environmental Health, 49 (6), 487-493.

- NGOs highly recommend substitution of PERC due to its hazard properties (e.g. Subsport)[xviii]

In the EU EDC database PERC is classified as a Cat 2 EDC with following argumentation:

> *“Epidemiological studies demonstrate that there is an increase of reproductive disorders that might be related to Endocrine Disruption. It is suggested that perchloroethylene affects the pituitary function in the brain. In the absence of evidence of hormone related mechanisms underlying the reproductive disorders in humans, Category 2 is deemed appropriate.“*

The following key information is cited from the EU EDC database:

> *“[…] women that work in dry-cleaning establishments may have a greater risk of having miscarriages as a result of exposure to the substance (Olsen, et al, 1990, Lindbolm, et al, 1992, Kyyronen et al, 1989; the substance appears to affect the pituitary function in the brain; endocrine disruption is suggested to be the mechanisms accounting for the increased risk of miscarriage following exposure (Zielhuis, et al, 1989, Ferroni, et al, 1992).”*

The SHVC roadmap to 2020[xix] clarifies the screening program for inclusion of relevant substances into the Candidate List. For EDC properties, the focus of the screening is stipulated to be initially on substances with an endocrine disrupting potential which are listed in the EU COM dbase as EDC, Cat 1 and Cat2:

> *“[…] since there is only limited information available in the registration database on the endocrine disrupting potential of substances, it is proposed that initially the focus would be on assessment of the endocrine disrupting potential of registered substances which are listed on the EU database (Endocrine Active Substances Information System) as Category 1 and Category 2 EDs…] (ECHA, 2013).”*

b) CoRAP[xx] evaluation by Latvia

Based on the information on the ECHA website, PERC has been included in the CoRAP list for substance evaluation on basis of the following initial ground for concern:

> *“Human health/CMR; Environment/Suspected PBT; Exposure/Wide dispersive Use; Aggregated tonnage”*

In the Justification documentation the following additional information is provided:

[xviii] http://www.subsport.eu/?s=perchloroethylene and http://www.subsport.eu/wp-content/uploads/data/perchloroethylene.pdf

[xix] http://echa.europa.eu/documents/10162/19126370/svhc_roadmap_implementation_plan_en.pdf

[xx] CoRAP justification document : http://echa.europa.eu/documents/10162/49a3c3f1-3afe-4816-a62b-82a8d64496fc

> *“The substance is a potential PBT with wide and dispersive uses. While substance is not available in consumer products, there is risk possibility of high exposure at the workplace. The substance has been assessed under the Existing Substances Regulation (EC) No. 793/93. The conclusion was that the ‘B’ criterion has not been met. However, taking into consideration classification (see Section 2.1), its market volume (see Section 3.3), and marginal case regarding bioaccumulation criterion, it is advised to further investigate use and exposure pattern for tetrachloroethylene. (Justification for the selection of a candidate CoRAP substance ; submitted by Latvia; 20/3/2013)”*

Currently, at the time of finalizing this AoA, the investigations by Latvia have ended. The conclusions are not yet known.

c) Analogy between metabolic processes for PERC and TCE

In various documents (EU RAR, 2004 (TCE)[xxi], SCOEL 2009 (PER)[xxii]), it is suggested that the same pathway for carcinogen effects might be applicable for TCE and PER.

According to the SCOEL report (2009) Perchloroethylene (PERC) is only slowly metabolised and accumulates in fat tissue as the unchanged compound. Rates of absorption by and removal from fat tissue are slow. Regardless of the route of exposure, the main route of elimination of absorbed PERC is via exhalation as the unchanged compound (about 95%). Metabolism of PERC occurs mainly by cytochrome P450-dependent oxidation and glutathione (GSH) conjugation.

Both the P450 and the GSH pathway are relevant to the TCE metabolism as well.

The analogy of the pathways related to TCE and PERC metabolism is of concern to Vlisco. Vlisco has the intention to move away from TCE to a more sustainable solution and not to another substance with potential SVHC properties. Indeed, in the SVHC Roadmap to 2020 Implementation Plan stipulates several times that structural similarity will be used a screening criterion for substances to be included in Candidate List.

> *“Examples of criteria which could be used to support substance selection: […], Structural similarity to substances on the Candidate List, to substances for which there is an intention to identify them as SVHC (i.e. in the Registry of Intention (RoI)) or to substances in the pool for RMO analysis.”*

[xxi] EU (2004). European Union Risk Assessment Report: Trichloroethylene. 1st Priority List, Volume 31. European Chemicals Bureau, European Commission, EUR 21057 EN, 2004.

[xxii] SCOEL (2009). Recommendation of the Scientific Committee on Occupational Exposure Limits for Tetrachloroethylene (Perchloroethylene). SCOEL/SUM/133 June 2009.

d) PERC: Sensitizing substance

PERC is self-classified as Skin Sens. 1B (H317). It is a concern to Vlisco that on this basis PERC could be considered an SVHC relevant for inclusion into Candidate List. Indeed, the SVHC Roadmap to 2020 stipulates:

> "*The SVHC Roadmap to 2020 lists as groups of substances to be covered by the implementation plan CMRs, sensitisers, PBTs and vPvBs, endocrine disrupters and petroleum/coal stream substances with CMR or PBT/vPvB properties.*"

To conclude on the evaluation of PERC as a potential SVHC, there are 4 arguments why in the future PERC could be included into Candidate List:

a. **EDC:** PERC is included in the EU EDC database as Cat 2 EDC and will according to the SVHC roadmap fall in the first batch of substances to be evaluated for inclusion into Candidate List. PERC is also associated with EDC properties outside the EU.
b. **PBT:** PERC is under investigation by Latvia in the context of substance evaluation for suspected PBT properties.
c. **Similarity between PERC and TCE:** The SCOEL report for PERC and the RAR for TCE indicate analogy between the metabolic pathways of both substances. It is of concern to the applicant that the hazard properties are therefore of the same concern.
d. **Sensitizing:** PERC is self-classified as Skin Sens. 1B (H317); sensitizing properties are part of the screening criteria of the SVHC roadmap.

3. Lack of regulatory framework to assess the risk of PERC

The alternative PERC is considered as an EDC, Cat 2 by EU COM.
For EDCs the possible risks to human health and the environment have not yet been fully understood[xxiii].

Currently the EU Commission is working on criteria for EDC. Furthermore, there is debate ongoing whether EDC are threshold or non-threshold substances. There is evidence to suggest that release to the environment and exposure to workers could cause risks. However, the control of risks is still uncertain since the hazards are not well understood and therefore the appropriate control measures to minimize the risk cannot be determined.

[xxiii] Cfr. argumentation for risk assessment of an alternative described in ECHA Guidance on Authorisation Applications, p 88. In the example of the guidance, a nanomaterial was assessed as alternative. For EDC a similar reasoning applies, i.e. lack of regulatory criteria to define an EDC

It can therefore be concluded that PERC has not been demonstrated to represent an overall reduction in the risk to human health and the environment as compared to the Annex XIV substance (TCE).

4. Exposure considerations comparing the use of TCE and PERC

In the CSR (Chapter 9 & 10) it has been demonstrated that the exposure to TCE as a result of Vlisco's operations has been minimized as far as technically and practically possible. This low level of exposure is the result of years of experience and optimization of the installation for the use of TCE. The introduction of PERC, having significant different physical properties, will require the replacement of the current equipment with other equipment. There are no details available yet on the de-waxing equipment with PERC, or on the PERC exposure directly related to this equipment. However it is clear that commercially available equipment is not as integrated as the current equipment, meaning there is no "ready to use" equipment available for the use as intended at Vlisco.

It is known however that is that the installation with PERC will require more operational staff (see Section 4.1.2.). Currently it is estimated that 16 additional people will be required. This is directly linked to more people being exposed and thus more people being at risk.

The following routes of exposure are of particular concern for PERC (besides the routes already described for TCE):

- Emissions via resin
- Emissions via cloth
- Emissions to waste water

<u>Emissions via resin</u>
As has been suggested above (Section 4.1.2.), the introduction of PERC with the current resin-solvent separation technology will lead to increased PERC concentrations in the resin (factor 9 higher in comparison to TCE). This does not cause a significant difference of the potential classification of the resin as the threshold for classification of a Carc. 2 is a factor 10 higher compared to Carc. 1B. Nevertheless, the increased concentrations could lead to significantly higher exposure in process. Currently it is not possible to determine the exact location where emission and exposure would take place as the installation will be different from the current TCE installation.
Therefore, it cannot be concluded that the risks related to PERC will be minimized to the same level as the current TCE risk levels.

<u>Emissions via cloth</u>
Initial tests with commercial PERC textile cleaning machines indicated that the PERC concentration in the cloth is similar to the TCE concentration in the cloth leaving the current de-waxing installation. As reported earlier, currently approximately 1,000 kg of TCE (per year) is emitted from cloth leaving the de-waxing unit. In the current installation, these emissions are local, controlled and minimized via Local Exhaust Ventilation. PERC has a higher boiling temperature and it is expected that PERC will not evaporate as much directly after extraction, but gradually during the next process steps. As the design of the PERC based installation is not final, it is not yet clear how PERC emissions from cloth during the full process can be minimized. Therefore, it

cannot be concluded that the risks related to PERC will be minimized to the same level as the current TCE risk levels.

<u>Emissions to waste water</u>

- Direct emissions of PERC in wastewater: higher concentrations of PERC compared to TCE.
  Due to the fact that PERC has a higher boiling point than TCE, the current water-stripping equipment will be insufficient to achieve the current concentration levels of TCE in the wastewater.

- Indirect emissions of PERC in wastewater via increased concentration in resin:
  The concentration of PERC remaining in the resin will be significantly higher than currently for TCE (factor 9, see Section 4.1.2.). As a result there will be an increase in PERC emissions to water via the rest resin concentration in the wastewater.

5. National legislations dealing with the use of PERC

Countries within the EU have identified the need to restrict the use of PERC in specific applications. In France and Denmark restrictions are in place on the use of PERC in dry cleaning installations for textiles. In France, no new dry cleaning installations are allowed to use solvent with a vapour pressure at 20°C above 1,900 Pa (including PERC) in a specific type of workshops.

In California PERC has been phased out from the use in dry cleaning. As of 2008 it is no longer allowed to install new dry cleaning equipment using PERC.

Conclusion on the reduction of risk due to transition from TCE to PERC

PERC has <u>not</u> been demonstrated to represent an <u>overall reduction in the risk to human health and the environment</u> as compared to the Annex XIV substance (TCE).

The main elements that led to this conclusion are:

(1) Although PERC is not a Carcinogen Cat. 1B as TCE, PERC is classified as a Carcinogen Cat.2..
  - There are several sources of information suggesting that the metabolic pathways of both chemical is similar
  - US-EPA considers PERC as a human carcinogen[xxiv] (cfr. Cat 1B)
  - Vlisco cannot judge the classification of PERC, however Vlisco is sincerely concerned to replace one carcinogen by another one.

(2) For the other endpoints for which TCE is classified for human health (Skin, Eye Irritant, Sensitizer, STOT SE3), PERC is classified as well. The association made for TCE with Parkinson's disease is also applicable to PERC.

[xxiv] http://www.epa.gov/ttn/atw/hlthef/tet-ethy.html

(3) It is currently unclear whether PERC fulfils the "SVHC" criteria listed in Art. 57 of REACH. However, there are several indications that PERC is an SVHC and could be included into Candidate List.

a. PERC is included in the Endocrine Disruptor (EDC) database[xxv] of the European Commission as EDC Cat 2,
b. PERC is listed on CoRAP[xxvi], and currently subject to substance evaluation by Latvia for concern over PBT and CMR properties and wide dispersive use,
c. There is an analogy between metabolic processes for PERC and TCE which might indicate the same mechanism for carcinogenicity
d. PERC is classified as Skin Sens. 1B (H317)[xxvii].

Based on the above, PERC could become subject to authorisation or restriction in the future. The concern over potential inclusion on the Candidate List is based on the criteria stipulated in the SVHC Roadmap 2020, Implementation Plan, 9 Dec 2013[xxviii]: screening on CMRs, sensitisers, PBTs and vPvBs, endocrine disrupters and petroleum/coal stream substances with CMR or PBT/vPvB properties.
A screening criterion used in the so called "Supplementary Activities" mentioned in the SVHC Roadmap, is *structural similarity* to substances on the Candidate List, on the RoI or in the pool of the RMO analysis. Knowing that PERC is structurally similar to TCE adds to the concern that a switch from TCE to PERC is not a sustainable solution.

(4) While the exposure to TCE is minimized in the current installation, it is unclear whether this will be equally possible for PERC. This is true particularly because the expected concentration of PERC in the resin will be a factor 9 higher than the current TCE concentration, potentially leading to additional diffuse sources of emissions. Additionally, the new PERC installation will need 16 additional people resulting in a larger population at risk.

(5) The risks of PERC and the mitigating measures (appropriate OCs and RMMs) can currently not be defined, due to lacking regulatory framework on endocrine disrupting compounds. Indeed, currently EU COM is working on EDC criteria. Today, there is no clarity whether EDCs will be considered as non-threshold substances. PERC is described as EDC, Cat 2 in the EU COM dbase. The risks and moreover the mitigating measures can currently not be defined, due to uncertainty on threshold/non-threshold.

For all the reasons stipulated above, PERC is not considered to be a suitable alternative as there is no convincing evidence available that the switch to PERC will result in a reduction of risk.

[xxv] EDC database EUCOM: http://ec.europa.eu/environment/chemicals/endocrine/strategy/substances_en htm

[xxvi] CoRAP: http://echa.europa.eu/documents/10162/49a3c3f1-3afe-4816-a62b-82a8d64496fc

[xxvii] Source: Regulation No 1272/2008 Annex VI (GHS/CLP)

[xxviii] SVHC Roadmap 2020 (9 Dec, 2013):
http://echa.europa.eu/documents/10162/19126370/svhc_roadmap_implementation_plan_en.pdf

4.1.5. Availability

PERC is available on the market in sufficient quantity.

Consultations with potential suppliers of equipment (see section 3.2.1 and section 4.1.2) have shown that **no** commercial equipment is available to remove the **resin from the cloth** in a continuous process or to meet the mentioned boundary conditions such as the level of PERC in the cloth and resin recovery. The commercial equipment will have to be adapted for this specific use. The technology for the modifications to the **resin-solvent** and **solvent-water** separation has not been identified yet.

An important aspect to evaluate for the commercial PERC-based resin removal equipment, is the reliability (MTBF: mean time between failure). Commercial equipment is typically not built for a full continuous 24/24, 7/7 operation as is the case for the applicant. Although some pre-engineering and testing has been done for a PERC based installation, the selection of the equipment still needs to be done. Only when this is done, the integration of the new equipment in the current installation can start. Because of the timing of this work and the delivery time of the equipment (typical 6-12 months), the technical modifications required for the use of PERC in the current installation will not be available by Sunset Date.

The current exploitation permit does not allow the use of PERC at the current location, and a modification of the permit to allow this use will need to be applied for. It is not certain that this permit will be granted (e.g. given the SEVESO aspect for PERC). Furthermore, in case a new exploitation permit is granted, specific, more stringent requirements on emissions to air of PERC could be applied. As these conditions are at present not known, no detailed investigation can be done to verify if the current air treatment installation will be sufficient to meet these requirements

The implementation of a PERC based resin recovery has an estimated time-line of 4 years. Because this alternative is part of the most likely non-use scenario, the applicant has initiated pre-engineering project, which it is hoped would allow the alternative to be available in case no authorization is granted, 2.5 years after the decision.

<u>Conclusion:</u>

> The alternative “use of PERC instead of TCE” is currently not available to the applicant. Several elements such as the exploitation permit and the required equipment are not available now. The development plan for the equipment shows that the required equipment will not be available by Sunset Date.

4.1.6. Conclusion on suitability and availability for Alternative 1.1

The overall conclusion is that PERC is currently not a suitable or available alternative. Most and for all, the use of PERC does not provide an overall reduction of risk. On regulatory level, the future of PERC is uncertain, which makes any investment high-risk, non-sustainable.

Technically it is not feasible for use instead of TCE today, as significant process development is still needed.

Economically it is not feasible, as it requires high-risks investments and increases operational costs and leads to loss of revenue during transition because the installation cannot be available by Sunset Date (April 2016).

The lack of an exploitation permit for the use of PERC and the uncertainty that this can be obtained for the current installation also makes PERC as an alternative not available.

It is estimated that technological development and investment to implement the PERC alternative would take approximately four years for Use 1. In the meantime, Vlisco would have to cease its Dutch Wax operations.

4.2. ALTERNATIVE 1.2: flammable solvent

The current solvent TCE is not flammable. Alternative 1.2 considers flammable solvents, which can fulfil the function of TCE. From the investigated solvents, mentioned in the list attached (Appendix B), Toluene has been identified as an alternative for investigation both for Use 1 and 2. In this case, Toluene would be a directly functional replacement for TCE as a solvent for the resin.

4.2.1. Substance ID and properties

Several solvents are evaluated for dissolving the resin from the cloth. They are mentioned in the research part and in Appendix B. For each of the solvents the following five relevant properties are mentioned:

Table 15: Relevant of properties of solvents which can be used to extract resin from cloth[50]

Property	Criteria
Speed of solubility for resin	[redacted] compared to TCE
Solubility of solvent in water	[redacted]
Flammability	Flashpoint < 55°C
Boiling point	[redacted]
Density compared to water	[redacted]

Toluene has been identified as the substance with technical functionality closest to TCE. This is based on recent intensive research on alternative flammable solvents (document 3a, Appendix A).

Table 16: Properties of Toluene

IUPAC name: Methylbenzene Other names: Toluene	
Identifiers	
CAS number	108-88-3
EC number	203-625-9
Properties	
Molecular formula	C_7H_8
Molar mass	92.14 g mol^{-1}
Density	0.87 g/cm^3
Melting point	-95 °C
Boiling point	111 °C
Solubility in water	0.47 g/100 mL (20 °C)
Hazards	
Harmonized	
Flam. Liq 2	H225
Asp Tox 1	H304
Skin Irrit. 2	H315
STOT SE 3	H336
Repr. 2	H361D
STOT RE 2	H373

IUPAC name: Methylbenzene Other names: Toluene	
Other Seveso	YES 7b
REACH status	
Substance is registered	

4.2.2. Technical feasibility

Toluene as flammable solvent

The current process installations at Vlisco have been designed for a non-flammable solvent. The installation does not comply with the ATEX[xxix] regulations for flammable liquids. Significant modifications would be required to the electrical part and the mechanical part of the installation to comply with ATEX. Also rotating parts such as pumps in combination with flammable liquids can pose a risk. This will not only have an impact on the equipment in direct contact with the solvent. Also equipment located near the location where Toluene is used, can be subject to ATEX.

Most probably the introduction of a flammable solvent would require relocation of at least a part of the installation to a new site suitable for the use of flammable liquids. This would limit the modifications to the ATEX regulations to the equipment directly involved in the use of Toluene and avoid modifications to other equipment. Relocation to such a new site would also avoid interference with the on-going production during construction.

[xxix] ATEX: ATmosphères EXplosive: regulation regarding the use of explosive substances (94/9/EG, 1999/92/EG)

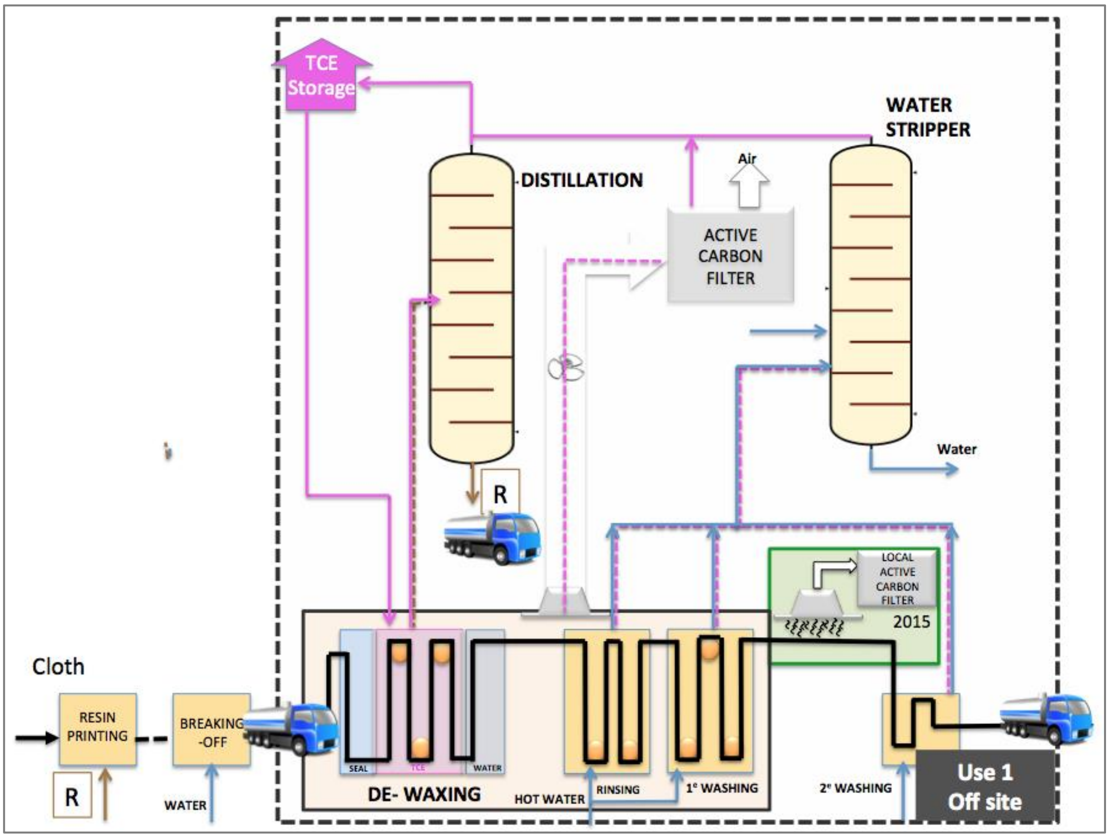

Figure 6: Relocation de-waxing off site

A possible concept would entail the relocation of the de-waxing step, including the resin-solvent separation (see Figure 6) to another site. There will be a logistic challenge to transport the recovered resin from the outside location back to the Helmond site. To reduce this, a pre-treatment step [redacted][51] step will have to be developed. This pre-treatment step will remove a significant part of the resin from the cloth prior to solvent de-waxing. By doing so the amount of resin to be treated at the outside location and to be transported back can be minimized.
The use of a flammable solvent for Use 1 off-site, can be combined with a non-solvent alternative on-site or, with the relocation of Use 2 to the same site as Use 1.
In case a permit would be granted for the use of a flammable solvent on site for Use 1 and Use 2, all operations can remain in Helmond.

Use of a solvent with different properties

All flammable solvents listed in Appendix B, meeting the criteria of Table 6 have a lower velocity for dissolving the resin. The extraction equipment has to be re-engineered for this different dissolving velocity. Because of its physical properties, similar problems are expected to arise with Toluene as explained for PERC. (see section 4.1.2.):

- Resin removal from the cloth
- Solvent removal from the cloth
- Resin-solvent separation
- Solvent-water separation

Each of these process steps is defined by the properties of the solvent used. Technical adaptions of the equipment need to take into account boundary conditions such as:

- Thermal stability of the solvent at temperatures required to separate the components
- Thermal stability of the resin
- Solvent-cloth and solvent-dye interaction

Several solvents have boiling points significantly higher than TCE (e.g. Toluene 111°C). For those solvents, (*i*) different technology will have to be developed for water stripping (*ii*) the solvent distillation will no longer be possible at current conditions or in the current installation; the process would require temperatures exceeding the temperature at which the resin is stable (*iii*) the concentration in the cloth after de-waxing is expected to be higher.

The research program so far has identified Toluene as a potential alternative solvent based on its physical properties. However the technical feasibility of toluene as solvent for de-waxing cloth has not been proven. Critical aspects such as cloth and dye interaction have not been investigated yet. The hazard profile of toluene is also not favorable.

After identification of a possible solvent, the development time for the process is estimated to six years. The only commercial available de-waxing installations are using PERC. There is no de-waxing installation commercially available which operates with Toluene. This means that such equipment still needs to be designed, and will be 100% custom made This explains for a large part the longer project time line. The complexity of the design of this de-waxing equipment lies with the compliance with the ATEX regulations. The applicant is not familiar with the technology to handle flammable liquids.

The search of an alternative flammable solvent and the development of a suitable process is part of the long-term development plan of the applicant.

Conclusion:

> The technical suitability of Toluene as an alternative to the use of TCE in Use 1 has not been proven. Significant development work is still needed. Based on the physical properties, the use of any of these solvents would require major reengineering of the equipment and major investments. Besides installing new equipment, part of the current equipment would also need to be modified to meet the ATEX regulations. None of the known flammable solvents is currently considered to be technically feasible. Currently the development for a Toluene-based alternative on-site is estimated to take six years.

4.2.3. Economic feasibility

As shown in the technical feasibility section, a de-waxing installation can either be built on the current site or on a new site. The choice depends in the first place on the possibility to obtain a permit for the use of a flammable solvent at the current location. In second instance the costs with both options can be compared. The following additional costs, associated with the implementation of these alternatives are considered:

- Capital cost
- Operational cost
- Costs associated with downtime

Costs associated with the remaining book value of the equipment, which is replaced, is not taken into account.
The following assumptions and parameters are adopted:

- Base period for calculating PV is 2016, calculated over the period 2016-2034. – This is longer than the period used for appraisal in the SEA, which is based on the decision horizon for authorisation decisions, and better reflects Vlisco's investment cycle in relation to these types of investments
- Discount rate is 10% - This is higher than the 4% discount rate mentioned in the ECHA SEA guidance, which is used in the SEA for this application, and reflects the higher cost of capital faced in the commercial sector compared with the societal perspective adopted in the SEA
- Constant fabric production volume over the assessment period; same as for 2014 (see section 4.1.3.)

4.2.3.1 Capital cost

As set out in section 4.2.2. the following main investments are to be considered:

- Design of Toluene based de-waxing equipment
- Replacement of current de-waxing equipment
- Additional pre-treatment of the cloth
- Alternative process for water stripping
- Modifications to resin distillation tower

- Modifications to make existing equipment ATEX compliant

or

- Infrastructure costs for new site

The investments costs were estimated based on budget prices for main equipment, standard engineering cost estimation for minor equipment and taking into account an installation factor (to cover insulation piping, instrumentation, etc). The level of detail of this scenario is less than the PERC-based alternative because of the greater uncertainty regarding the technical and logistical feasibility of this option. Details are provided in the. Table 17 below:

Table 17: Breakdown of investment costs of Alternative 1.2[52]

Type of cost	Description	Cost estimate (€million)	
		On Site	Off Site
New Equipment	Flammable solvent based de-waxing equipment Additional pre-treatment of the cloth Upgrade of existing equipment to ATEX.	[redacted]	[redacted]
New Site	Land + infrastructure.	[redacted]	[redacted]
Installation	Installation factor 0,6	[redacted]	[redacted]

Type of cost	Description	Cost estimate (€million)	
Contingency	This is ~10% of the budget mentioned in the sub-projects, for unknown expenses that may arise. It is good practice to avoid "optimism bias" by allowing contingency for unspecified risks[xxx].	[redacted]	[redacted]
Engineering and Project management support	Vlisco are not able to internally manage a project this size Estimated Engineering and project management is 20% of equipment and installation cost	[redacted]	[redacted]
Total		[redacted]	[redacted]
	PV	[redacted]	[redacted]

Note

1. Upgrade of existing equipment only for on-site alternative.
2. Installation factor: factor used to estimate the cost of construction based on the cost of the equipment. This factor depends on complexity of the installation. The factor was established by an engineering company "IV industries" in a report prepared for Vlisco.

There is no installation available today at Vlisco to handle Toluene. Such an installation needs to be designed and installed. It was estimated that this takes about 6 years for an on-site installation. This is significantly longer compared with PERC:

- Less research has been done so far with Toluene
- No off-the-shelf equipment (de-waxing) is available, so design of equipment is needed
- Extension or new permit is required, which can only be requested when basic design is available
- Increased complexity by either upgrading existing equipment for ATEX or relocation to new site.

An off-site installation is estimated to take seven years, one year extra compared with an on-site installation, because of following elements:

- Search for new location
- Permit for the new location. This can only be started after a basic design is available. Construction cannot start before permit is granted

4.2.3.2 Operational cost

It is assumed that the concept of the Toluene based machines will be similar to the PERC based machines. As a result the integration of these machines into the rest of the Vlisco process will be

xxx HM Treasury (2003) - THE GREEN BOOK Appraisal and Evaluation in Central Government - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf similar as for PERC. Because of this lack of full integration, additional headcount was estimated for PERC. The same number of additional FTE is assumed for the Toluene based equipment. This additional headcount (16 FTE) is to be taken into account both for the on-site and for the off-site case.

In case the de-waxing is done off-site at a new location, specific additional costs are to be taken into account:

- Additional overhead headcount 16 FTE (daytime)
- Site infrastructure
- Logistics costs transport of resin and cloth

The 16 additional FTE's are estimated to cover local supervision, logistics, safety and maintenance positions. The site infrastructure cost covers maintenance, insurance, energy, etc

On-site: The yearly additional cost is estimated at [redacted] [53]€. Period 2022-2034 (PV [redacted] €[54])

Off-site: The yearly additional cost is estimated at [redacted][55]. Period 2023-2034 (PV [redacted])[56]. €)[57]

4.2.3.3 Downtime Costs

As mentioned before, the alternative can be located on the current site or on a new site. In case of a construction on-site a six-year project is foreseen, while in case the construction is on a new site, the project will last seven years. If authorisation is refused, there will be (at best) a 6 or 7-year period during which wax prints (and ready to wear clothes made with wax prints) cannot be made as they are dependent on the use of TCE. After decision of non-authorisation, Vlisco will start the engineering project for the installation of this alternative. It is estimated that the project will be available for production, 6 or 7 years after Sunset Date. In the period between Sunset Date and completion of the project, Vlisco will not be able to produce any wax-based product. This will result in a significant loss of sales during that period.

Because of the longer period (compared with Alternative 1.1) during which no wax fabric production is possible, it would not be financially viable to retain the current permanent workforce, and Vlisco will need to try to avoid all direct costs related to the production of wax fabrics. In this case, a more correct approach to the estimation of the costs of this option is based on the loss of profit. To be consistent, the same profit margin is used (see Table 10) as for alternative 1.1.

However there is a direct cost associated to laying-off personnel. Due to the age profile of the workforce at Vlisco, a redundancy cost of one year's worth of salary is estimated per FTE total (estimated cost [redacted] €)[58].

The production process of Vlisco is complex and significant training will be needed for the newly hired personnel when the plant starts up again. A training period of one year is foreseen. This timing is based upon the fact that it takes significantly longer to train personnel when an installation is under construction, with little or no personnel with experience working with the installation, compared with training in an installation in production.

The last phase of the implementation of a new installation consists of

- Testing
- Start-up

- Optimizing
- Re-entry in the market

It is estimated that these four steps.it will take one year of the project. During this last year of the six-year project, all normal costs of production are taken into account in de cost estimation. These costs include headcount, energy and raw materials costs. Impact of lost production can be estimated in that case on the basis of the lost sales revenue.

Table 20 and Table 21 show the estimated loss to Vlisco over this period (May 2016 to end 2021 or 2022). These figures are optimistic for several reasons:

1. It assumes there are no delays in the 6 or 7 year period needed for construction and testing of production lines. Unforeseen delays with equipment suppliers, availability of construction workers/management, weather, product testing and so forth are possible.
2. It assumes that, following pilot testing and R&D, there is no unintended loss in wax print quality due to using Toluene rather than TCE.
3. It assumes that once built, the new production lines will be fully operational (e.g. <85% operating capacity) after commissioning.
4. It assumes that Java production, that is not dependent on using TCE, can be fully operational whilst there is on-going construction to build new production lines. Java prints are made using different technology (and on separate production lines) so may be less affected. However, in practice it might not be possible, due to health and safety reasons, to have production staff working during construction to retrofit the wax print production lines.
5. It assumes that demand (Vlisco's market share) will automatically return to the level of 2014 once the new production lines are fully operational. As set out in Section 2.2 of the SEA, the African prints market is competitive and the competition is improving in terms of quality of their products. An absence of Vlisco wax prints for 6 to 7 years could lead to a reduction in demand due to reduced brand awareness, reputation and loyalty.
6. It takes no account of additional costs associated with mothballing, maintaining and restarting wax production facilities during the suspension of wax fabric production.

Off site Flammable solvent	**(€ million)**					
	2016 (6 months)	**2017-2020**	**2021**	**2022**	**Total**	**Total (PV)**
Lost profit	[redacted]	[redacted]	[redacted]		[redacted]	
One time costs	[redacted]		[redacted]	[redacted]	[redacted]	
Downtime Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 18: Cost of downtime for Alternative 1.2; off-site option[59]

On site Flammable solvent	**(€ million)**					
	2016 (6 months)	**2017-2019**	**2020**	**2021**	**Total**	**Total (PV)**
Lost profit	[redacted]	[redacted]	[redacted]		[redacted]	

On site Flammable solvent	(€ million)					
	2016 (6 months)	2017-2019	2020	2021	Total	Total (PV)
One time costs	[redacted]		[redacted]	[redacted]	[redacted]	
Downtime Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 19: Cost of downtime for Alternative 1.2; on site option[60]

Notes:

1. Figures have been rounded to nearest whole number to avoid false accuracy

4.2.3.4 Conclusion

Table 20 summarizes the preceding discussion and presents the estimated costs of implementing the flammable solvent alternative for Use 1. The total present value cost over the period 2016-2034 is estimated to be around [redacted][61] (discounted at 10%, depending on-site or off-site). The largest proportion of this cost is the estimated loss of profit due to the need to cease production during the implementation period (and, as has been discussed, lost profit probably underestimates the true costs of temporary closure to the company even after accounting for additional costs of redundancy and rehiring)). There will also be a permanent increase in operating costs via increased labour requirements, as well as costs of investment associated with the installation of facilities on the new site.

The conclusion is that the alternative to switch to Toluene for Use 1 is currently not economically feasible, neither on-site, nor in the case of an installation on a new site.

Table 20: Overview costs Alternative[62] 1.2

Different flammable solvent for dissolving current resin from the cloth: Toluene		
Implementation time On-site Off-site	 6 years 7 years	- New Toluene-based de-waxing equipment to be designed - Construction and installation of new de-waxing - Modification of resin-solvent separation - Alternative water stripping technology - No wax production, during implementation - Modification of existing equipment (on-site) for ATEX or - Development of new site, including site location and permitting
Investment cost (PV) On-site	 [redacted]	- New equipment and installation of equipment - Modification of equipment

Different flammable solvent for dissolving current resin from the cloth: Toluene		
Off-site	[redacted]	- New site
Impact on OPEX (PV) On-site	[redacted]	- 16 additional FTE in period 2022-2027
Off-site	[redacted]	- 16 additional FTE (shift) in period 2023-2027 - Additional overhead cost
Transition cost (PV) On site	[redacted]	- No production of wax product during 6 years
Off site	[redacted]	- No production of wax product during 7 years
Total (PV) On site	[redacted]	
Off site	[redacted]	

4.2.4. Risk reduction potential

The overall reduction of risk has not been investigated in detail as for none of the alternatives the technical feasibility has been proven. Moreover the economical feasibility is less favourable compared with the non-flammable solvents, so priority has been given to this range of solvents for further investigation.

Similar to PERC, Toluene has also a higher boiling point compared with TCE. Hence, it can be expected that the evaporation of remaining solvent from the cloth after de-waxing will also be more gradual and more spread out in the process (see section 4.1.2.). As such, without details on alternative equipment or processes, it has to be taken into account that the total exposure to toluene could be higher even in an other installation, compared with the current exposure to TCE.

It is however clear that the use of a flammable solvent introduces a new significant risk in the production process. The current solvent, TCE, is non-flammable and as such provides no explosion risk. The alternative toluene is SEVESO (7b: flammable liquid) classified. This risk can technically be handled, at a significant cost, following the ATEX regulations. Toluene has recently been subject to substance evaluation. In the conclusion from the Member State, it was not proposed to bring the substance forward for authorisation or restriction.

<u>Conclusion:</u>

> There are flammable solvents available with a more favourable hazard profile compared to TCE. The exposure to the solvent cannot be estimated without details on the installation, in the current installation using a solvent with a higher boiling point will always lead to a

higher exposure. However, the use of flammable solvents introduces a new and significant risk in the process. This risk can be handled but at a high cost.

4.2.5. Availability

Toluene is available in sufficient quantities and composition.
The installation cannot be available at the Sunset Date. The required development work requires six years for an on-site installation.

The introduction of flammable solvents will require either an update of the current exploitation permit for the current location or, more probably, a new exploitation permit for another location. No location has been identified, nor does Vlisco have other production sites in the EU where this process could be installed. Finding and acquiring a new location can already take more than one year. Preparing and obtaining a permit for exploitation can take one to two years. Because a request for exploitation permit can only be submitted when the new location is known and the basic design is available, the relocation can have a significant impact on the overall timing of the project.
A six year development and implementation time is expected for an on-site installation. For an off-site installation, a seven year implementation time is estimated.

Conclusion:

Conditions for the implementation of the technology, such as an exploitation permit are not in place.
For Toluene, a substance subject to SEVESO directive, it is unclear if a permit for the use of it on the current production location in Helmond will be granted. Introducing a flammable solvent will require most probably a relocation of Use 1. A new location is not available today and will not be available by Sunset Date.

4.2.6. Conclusion on suitability and availability for Alternative 1.2

A number of flammable solvents have been investigated. Based on a first screening, Toluene was identified as a potential alternative for Use 1. The use of flammable solvents for Use 1 is currently not a suitable or available alternative.

For Use 1 the technical feasibility for the removal of resin at Vlisco is not proven. A six year development and implementation time is expected for an on-site installation.

The costs of implementation can only be estimated with significant uncertainty because the technical concept is not complete, but it is already clear that economic feasibility will be much less favourable compared to a non-flammable solvent due to the adaptations needed to meet the ATEX regulations and the re-location of a part of the production. The long implementation period will necessitate a temporary shutdown of Vlisco’s Real Dutch Wax operations, with significant profit losses.

Neither the technology nor the location will be available by Sunset Date.

4.3. ALTERNATIVE 1.3: Rosin and Solvent free extraction

In this alternative, a different resist is used in Use 1 in combination with an alternative technique to replace the function of TCE as a solvent in Use 2. There is a strong technical interaction between the two alternatives (Rosin for Use 1 and solvent free extraction for Use 2) that makes evaluating the two alternatives separately impossible. This alternative 1.3 is the same as the alternative 2.3 described in AoA Use 2.

The current resist, used in Use 1, is a synthetic resin. In the past a wood-based rosin was used as a resist. This use was discontinued more than 30 years ago due to a shortage on the world rosin market. When the use of rosin was stopped, a limited recovery process (max 60% of the rosin was recovered) was in place using TCE.

By the introduction of this alternative resist, potentially other solvents or other techniques can be introduced for the removal of the alternative resist from the cloth. More specifically, water (alkali) could be used to remove the resist from the cloth.

4.3.1. Substance ID and properties

The alternative for the use of TCE as a solvent for resin, is the use of an alternative resist (wood rosin as resist). This resist can be extracted from the cloth with different techniques compared with resin i.e. without TCE. It has the same function as resin, as a mechanical resist in the dye process and should to be capable to produce the same look of the final product (eg bubbling effect). Although it is still to be proven that this can be achieved.
Because of the chemical interaction of the new resist with other process chemicals, additional process steps will be required.

Table 21: Properties of the rosin

1.1.1 IUPAC name: Abieta-7,13-dien-18-oic acid Other names: rosin	
Identifiers	
CAS number	514-10-3
EC number	208-173-3
Properties	
Molecular formula	$C_{20}H_{30}O_2$
Molar mass	302.45 g mol^{-1}
Density	1.06 g/ml
Melting point	140 °C
Boiling point	439.5 °C
Hazards	
R-phrases	R36/37/38
S-phrases	S26 S36

4.3.2. Technical feasibility

A concept has been developed for the use of this resist instead of resin. This concept is based on (*i*) the historical process, (*ii*) recent developments of the Vlisco process, and (*iii*) current product requirements. The engineering concept includes additional steps in comparison with the current installation with resin. The additional steps are needed to overcome the technical problems with the alternative resist. The design of the process and the technical feasibility are not well known to date. Significant development and engineering is still required.
An overview of the different process steps and streams is provided in Figure 7[63]. The new steps of the process are indicated in the shaded boxes. The figure shows the solvent free extraction for Use 2 and the strong interaction with Use 1.

[redacted]

Figure 7: Process with alternative resist

The process is based on the availability of chemically modified natural rosins, which may have better properties than wood rosin. [redacted][64]. The rosin must have the following properties:

- Chemically inert towards inks and colorants
- Chemically inert during fixation of the dyes
- Chemical removal of resist from the cloth
- T_{glass} can be controlled during production of cloth and recovery of resist

Following specific problems are expected with the introduction of this resist. For the sake of overview, new steps related to Use 2 to allow the use and recovery of the resist are also discussed here:

- **R**[redacted]

[redacted] Figure 7 [redacted]

[redacted]

[redacted]

- [redacted].[65]

Technical feasibility of the process will be further investigated during the long term R&D program. Also technical feasibility of the end product (same look and feel) will be assessed.

Conclusion:

The use of this alternative resist in the current process is not technically proven. Significant process development is still needed to allow this. The program to achieve this is estimated to take 9 years including 3 years for the feasibility study and start-up.

4.3.3. Economic feasibility

Because of the integration of the process, it is difficult to consider the economical feasibility of this alternative separate for Use 1 and Use 2. The investment and operational costs are specific for this combination of alternatives. As demonstrated in section 4.3.2. additional investments are required in the de-waxing process to allow the use of this resist in a solvent free extraction. The following additional costs, associated with the implementation of these alternatives are considered:

- Capital cost
- Operational cost
- Costs associated with downtime

Costs associated with the remaining book value of the equipment, which is replaced, are not taken into account.
The following assumptions and parameters are adopted:

- Base period for calculating PV is 2016, calculated over the period 2016-2034. – This is longer than the period used for appraisal in the SEA, which is based on the decision horizon for authorisation decisions, and better reflects Vlisco's investment cycle in relation to these types of investments.

- Discount rate is 10% - This is higher than the 4% discount rate mentioned in the ECHA SEA guidance, which is used in the SEA for this application, and reflects the higher cost of capital faced in the commercial sector compared with the societal perspective adopted in the SEA.

- Constant fabric production volume over the assessment period; same as for 2014 (see section 4.1.3.)

4.3.3.1 Capital cost

As set out in section 4.3.2. the following main investments are to be considered:

- Design and development of new process technology for [redacted]
    - [redacted][66]

The investments costs were estimated based on budget prices for main equipment, standard engineering cost estimation for minor equipment and taking into account an installation factor (to cover insulation piping, instrumentation, etc). The level of detail of this scenario is less compared with Alternative 1.1 because of the conceptual development still needed. Details are provided in the Table 22 below:

Table 22: Breakdown of investment costs for Alternative[67] 1.3

Type of cost	Description	Cost estimate (€million)	
		Use of resist (Use 1)	Solvent free extraction (Use 2)
New Equipment	Design and installation of equipment	[redacted]	[redacted]
Installation	Installation factor 0,6	[redacted]	[redacted]
Contingency	This is ~10% of the budget mentioned in the sub-projects, for unknown expenses that may	[redacted]	[redacted]

Type of cost	Description	Cost estimate (€million)	
	arise. It is good practice to avoid "optimism bias" by allowing contingency for unspecified risks[xxxi].		
Engineering and Project management support	Vlisco are not able to internally manage a project this size Estimated Engineering and project management is 20% of equipment and installation cost	[redacted]	[redacted]
Total		[redacted]	[redacted]
	PV	[redacted]	[redacted]

Note

1. Installation factor: factor used to estimate the cost of construction based on the cost of the equipment. This factor depends on complexity of the installation. The factor was established by an engineering company "IV industries" in a report prepared for Vlisco.

There is no installation available today at Vlisco for the use of this resist in a dyeing process or for the recovery of this resist by means of solvent free extraction. Such an installation still needs to be designed and installed. It was estimated that this would take about 9 years. This is development time mainly driven by:

- Complex chemistry of this resist in combination with various types of ink
- Development and optimization of the solvent free extraction technology

4.3.3.2 Operational cost

The success of this alternative depends largely on the extent to which it is possible to achieve sufficient rosin recovery rates. But even in the most optimistic case, the rosin recovery rate will be lower compared with the current situation. The unit cost for this resist (3-4 €/kg) is also higher compared with the cost of resin (1,81 €/kg).
In section 4.3.2. an estimate is provided of the possible resist losses in the different process steps:

- Rinsing step: [redacted][68] additional loss of resist;
- Colour dyeing and fixation: It is estimated that [redacted][69] of the resist on the cloth will be saponificated during the colour fixation process.
- De-waxing step: In case none of the resist can be recovered, there will be a [redacted][70] additional loss. The success of this alternative will depend in large part on the success in minimizing the losses in this step.
- Recovery (Use 2): separation of the resist from the water after acid washing is estimated to have an efficiency of [redacted][71]. The solvent free extraction is also to be expected to have an

xxxi HM Treasury (2003) - THE GREEN BOOK Appraisal and Evaluation in Central Government - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf efficiency of [redacted][72]. In total for these 2 steps and additional loss of resist of [redacted][73] is expected

Total rosin loss is estimated to [redacted][74], representing a yearly cost of [redacted] €[75] (Use 1) and [redacted] €[76] (Use 2).

In the solvent free extraction process the remaining water from the rosin is evaporated in equipment capable of handling the viscous product. It is expected that the energy demand of this process will be higher compared to the evaporation of a lower boiling solvent such as TCE in the current resin distillation process.

The PV of the increased operational cost for the period 2025-2034 for Use 1 is [redacted] €[77]
The PV of the increased operational cost for the period 2025-2034 for Use 2 is [redacted] €[78]

4.3.3.3 Downtime Costs

It is estimated that the option would be available for production, 9 years after Sunset Date. In the period between Sunset Date and completion of the project, Vlisco will not be able to produce any wax-based product. This will result in a significant loss of sales during this period.

The same argumentation and methodology as in section 4.2.3.3 can be applied here.

Table 23 sets out the estimated loss to Vlisco over this period (May 2016 to end 2024)

Table 23: Cost of downtime for Alternative 1.3[79]

Use 1: Rosin + solvent free extraction	(€ million)					
	2016 (6 months)	2017-2022	2023	2024	Total	Total (PV)
Lost profit	[redacted]	[redacted]	[redacted]		[redacted]	
One time costs	[redacted]		[redacted]	[redacted]	[redacted]	
Downtime Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes:

1. Figures have been rounded to nearest whole number to avoid false accuracy

4.3.3.4 Conclusion on economic feasibility of Alternative 1.3

Table 24 summarizes the preceding discussion and presents the estimated costs of implementing a different resist for Use 1, in combination with non-solvent extraction of the resist for Use 2. The total present value cost over the period 2016-2034 is estimated to be around [redacted][80] (discounted at 10%) for Use 1. By far the largest portion of this cost is the estimated loss of profit (and additional costs) due to the need to cease production during the very long expected implementation period (and, as has been discussed, lost profit probably underestimates the true costs of temporary closure to the company). There will also be a permanent increase in operating costs via increased raw material consumption, as well as costs of investment associated with the installation of new facilities. The long-term viability of this alternative will depend on the success to minimize the losses of resist to reduce the additional operating cost.

The conclusion is that the alternative to switch to this new resist for Use 1 is currently not economically feasible.

Table 24: Overview costs Alternative 1.3[81]

Different resist (rosin) (Use 1) and recovery of rosin by solvent free extraction (Use 2)		
Implementation time	9 years	- Design and installation of Rosin based process - Design and installation of solvent free extraction in combination with the use of other resist
Investment cost (PV) Use 1 (Rosin) Use 2 (Solvent free extraction)	[redacted] [redacted]	- New equipment and installation of equipment - Modification of equipment
Impact on OPEX (PV) Use 1 (Rosin)	[redacted]	- 30% loss of rosin use - Increased raw material cost
Use 2 (Solvent free extraction)	[redacted]	- 20% loss of rosin use - Increased raw material cost
Transition cost (PV)	[redacted]	- No production of wax product during 9 years
Total (PV)	[redacted]	

4.3.4. Risk reduction potential

The overall reduction of risk has not been evaluated further as the alternative has been disregarded on grounds of technical feasibility and economical feasibility.
Rosin is a by-product of the paper production and as such a much more sustainable product compared to the synthetic resin. Gum-Rosin is tapped from production trees.
For this alternative no solvents are needed. Hence, operators have no contact with a solvent and there are no solvent emissions to the environment. The emissions of rosin, salts and pigments to water and the impact of this on the requirements for the wastewater treatment are still to be investigated. Some rosins have sensitizing properties which is an issue in a process where there is a possibility of skin contact with the cloth with the printed rosin.

4.3.5. Availability

This alternative will not be available by Sunset Date. Most of the production machines for this alternative are available but need to be designed for this specific use. A suitable rosin still needs to be identified. The rosin, which was used in the early days at Vlisco, is too reactive for the current process and cannot be used.
It is estimated that it will take at least another 3 years of development, especially for the use of rosin, before it can be established if rosin can provide an alternative to resin. After this initial research period another 6 years are needed to develop the process itself. Total time before an

industrial installation will be available, is estimated to 9 years including start-up. The development of the solvent free extraction will be delayed by this initial investigation. The design of the solvent free extraction (Use 2) will depend on the outcome of the investigation on alternative resist (Use 1).
The exploitation permit will have to be adapted for the increased emission of rosin and salts via the wastewater. It is unclear what level of emission will be allowed and what additional measures on the local wastewater treatment will be imposed in the permit.

Conclusion:

The alternative is not available now and will not be by Sunset Date. The development program for this alternative for Use 1 and Use 2 is estimated to be nine years.

4.3.6. Conclusion on suitability and availability for Alternative 1.3

The use of rosin as an alternative resist is not considered to be a suitable alternative. Technically it is not a feasible alternative. Although a concept is available, so far research has not found solutions for the different problems associated with the use of rosin. Another major challenge is the recovery of the rosin for which there is no process available yet. The economical feasibility of the Alternative will depend largely on the ability to increase the recovery rate of the resist.
Rosin is an alternative resist and allows potentially a solvent free operation. The development of the rosin-based technology could therefore be part of the long-term development plan of the applicant. It is estimated that it will take at least another three years of development, especially for the use of rosin, before it can be established if rosin can provide an alternative to resin. After this initial research period another six years are needed to develop the process itself. Total time before an industrial installation will be available, is estimated to nine years including start-up.

4.4. ALTERNATIVE 1.4: Mechanical removal of resin

In this alternative, it is investigated if the function of the solvent can be replaced with another technique to completely remove the resin that is deeply penetrated in the yarn (melted-in resin). It needs to be pointed out here that after the breaking-off process, the resin is melted-in in the cloth by means of heat. Reason being that the resin needs to be sufficiently bond to the cloth during the following process steps. Without this, serious quality defects occur.

4.4.1. Description of technique

The technique implemented by Vlisco to dye the cloth, consists of applying dyes in various steps (Figure 2). Early in this process, a mechanical resist needs to be applied to control where the dye will and/or will not be on the cloth.

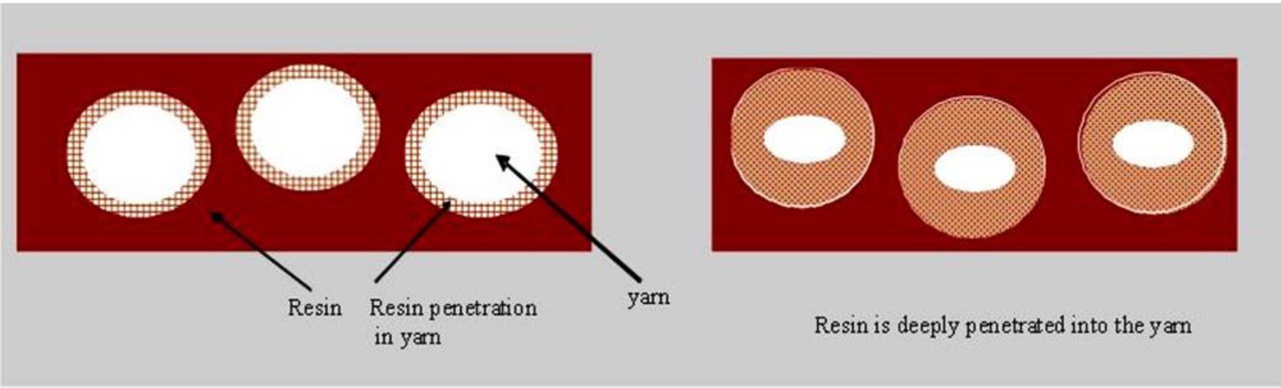

Figure 8: Penetration of resin into the yarn

The depth of penetration of the resin into the yarn is an important process parameter to control. However more deeply penetrated resin is also harder to remove from the yarn. Resin, which is deeply penetrated in the yarn, is called melted-in resin.

Research has been done to remove the melted-in resist mechanically. Two techniques seemed promising (see also § 3.2):

- **Removing by mechanical force:** combination of mechanical force and rinsing with water
- **Removing by ultrasonic waves:** leading the cloth over sonotrodes and rinsing of the resin with water

Based on this research, concepts for the removal of the resin have been developed.

Removing by mechanical force (Figure 9**)**
The resin is removed from the cloth by a series of breaking units each time followed by a water rinsing step.

[redacted]

Figure 9: Concept for removal with mechanical force[82]

Removing by ultrasonic waves (Figure 10)

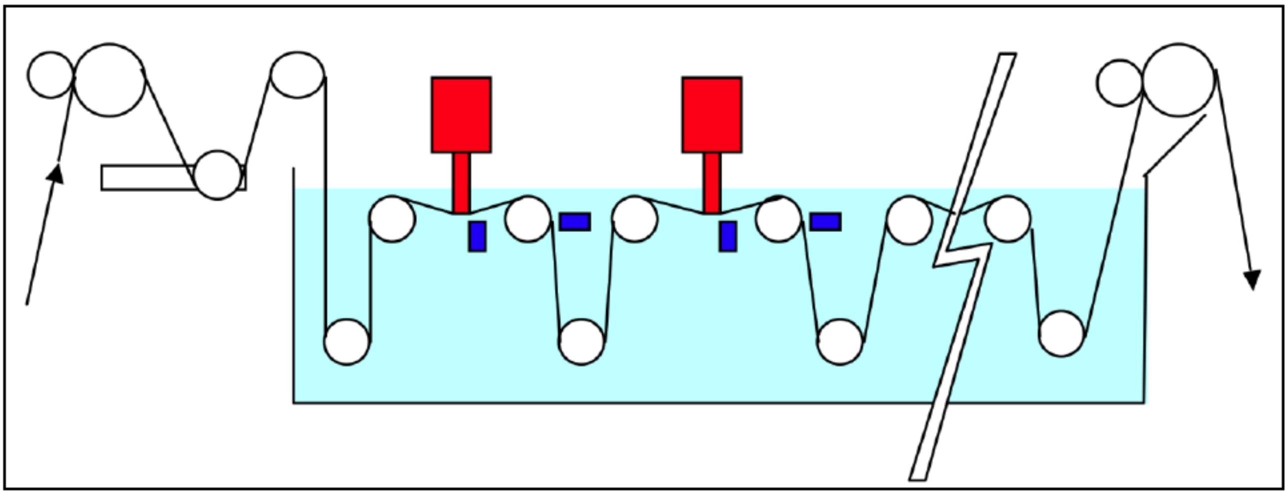

Figure 10: Concept for removal with ultrasound

For this technique, the cloth with resin is guided along two ultrasonic wave generators where the resin is removed by cavitation created by the sound waves. In between and after the wave generator, the loose resin is washed off from the cloth with water.

If successful, both techniques would eliminate the use of a solvent for Use 1. However, both techniques still yield process water loaded with resin, which is to be recovered in the process described in Use 2 of this application dossier.

4.4.2. Technical feasibility

Tests have shown (Appendix A, doc 71, doc 72; doc 102 doc 91; doc 109) that it is not possible to remove the resin if melted-in. Mechanical and/or ultrasonic removal of resin is only possible in case the resin is not penetrated in the yarn.

These techniques can only be successful if the resin process itself can be changed in such a way that the resin does have to penetrate into the yarn. Trials have shown the difficulty of this. Without the melted-in resin, the resulting image was of inferior quality and not suitable for sale.

[redacted][83].

Conclusion:

> Mechanical removal or removal by ultrasound of all resin is technically not possible. On the other hand, unless the resin is melted-in, it is not possible to generate the desired final product. Hence, mechanical de-waxing is technically not a suitable alternative.

4.4.3. Economical feasibility

Economical feasibility of mechanical removal or removal by ultrasound have not been investigated in detail as the alternative is considered as not technically feasible with melted-in resin.

Using not melted-in resin has a significant effect on the product look and quality. The economical effect of selling product with inferior quality has been investigated in alternative 1.5 (§ 4.5). The same conclusion is applicable here; the price of product with inferior quality, will erode to the level of the commodity RSP product which in Helmond is economically not sustainable.

4.4.4. Risk reduction potential

This aspect has not been investigated further, but no solvents are used in these processes. Overall it can be assumed that the risk in using these processes is lower compared to the use of TCE.

4.4.5. Availability

Equipment using ultrasound is available on the market and has been used for trials. Full scale installations have to be designed and custom made to the use at Vlisco. None of these machines is capable to fully remove the resin.

Designs for mechanical de-waxing machines are available on the market. None of these machines are able to fully remove the resin.

Conclusion:

The equipment for removal, either mechanically or by ultrasound, of all the resin is currently not available.

4.4.6. Conclusion on suitability and availability for Alternative 1.4

Mechanical de-waxing and de-waxing using ultrasound have been tested extensively and have proven to be not suitable for melted-in resin.

Mechanical de-waxing or de-waxing using ultrasound can only remove the resin completely from the cloth in case the resin is applied on the surface of the cloth. However, without melted-in resin, it is not possible to create the desired product look.

Technically the alternative is not feasible. Non-solvent de-waxing is not a suitable alternative.

4.5. ALTERNATIVE 1.5: Printing techniques

The function of TCE as a solvent for a resist in a cloth dyeing process becomes redundant in case the same product can be produced by an alternative imaging technique. These alternative techniques are considered in this alternative.
It is clear that if these alternatives were suitable, there would no longer be a need for a mechanical resist, which would also eliminate the need for a solvent in Use 1. But this would also eliminate the need of an extraction process to extract resin from water, thus eliminating the need for Use 2

4.5.1. Description of the alternative technique

Two direct printing techniques were considered in the past (see § 3.2):

- Rotary & flatbed screen printing
- Ink jet printing

<u>Rotary Screen printing (RSP)</u> is a technology used to print a design image on textiles. The applicant is aware and familiar with this technology as this is used a.o. for their Java product line (See SEA for details). Since flatbed is a less suitable technique than rotary screen printing for Vlisco, only RSP is discussed further

Screen printing is by far the most popular technology in use today for textile printing. Screen printing consists of three elements: the screen which is the image carrier; the squeegee; and ink.

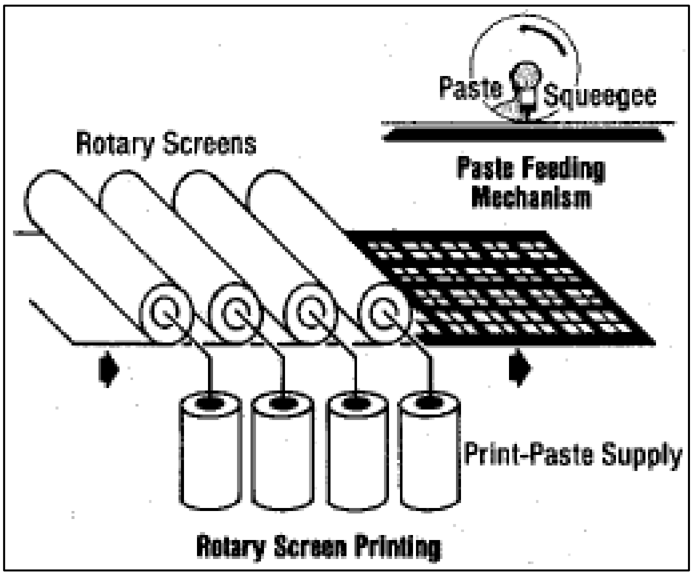

Figure 11: RSP principle

In rotary printing, the fabric travels at a consistent speed between the screen and a steel or rubber impression roller immediately below the screen. As the fabric passes through the rotary unit, the screen spins at a rate that identically matches the speed of substrate movement.

The squeegee on a rotary press is in a fixed position whereby its edge makes contact with the inside surface of the screen precisely at the point where the screen, substrate and impression roller come together. Colour paste is automatically fed into the centre of the screen and collects in a wedge-shaped “well” formed by the leading side of the squeegee and the screen’s interior surface. The motion of the screen causes this bead of colour paste to roll, which forces colour paste into stencil openings, essentially flooding the screen without requiring a flood bar. The squeegee then shears the colour paste as the stencil and substrate come into contact, allowing the colour paste to transfer cleanly to the material.

Characteristic of rotary screen printing is a repeating design with a length of the circumference of the screen. This repetitiveness is a concern to Vlisco. For the Vlisco wax fabrics, every yard must be unique.

Inkjet printing is a digital printing technology in which the dye is transferred on the fabric as little drops. There are 4 to 8 base dyes that are printed on the fabric. The mixture of the dyes and the amount of each dye determines the end colour that is visible on the fabric.

For inkjet printing special inks are required with high grade of purity, which leads to high cost prices of these inks.

Printing designs can in theory be infinite.

For printing cotton, reactive and pigment dyes are available. The limitation of ink jet printing lies specifically in the limited colour range that can be reached.

An essential difference between these techniques and the dye process of Vlisco is the fact that a dye process is two-sided by default. Both sides of the cloth are treated in one process step. Both alternative techniques, RSP and inkjet are in the first instance one-sided techniques.

4.5.2. Technical feasibility

By nature of this technique, **RSP** can only produce repetitive images and only on one side at a time. This is significant different from the “Real Dutch Wax” product where there is randomness which cannot be recreated with the RSP technology (see also Appendix C). The same is true for flat bed printing. Furthermore, flat bed printing typically has a lower capacity.
Vlisco has in the past extensively researched this technique (see Section 3.2.1.) but could never obtain the same product look as the “Real Dutch Wax”. Beside the repetitive nature of the design, RSP only allows specific dyes to be used (eg no indigo), which match together (same fixation mechanism) and cannot create the typical crackle lines. As a result, a different look is obtained with a more limited colour range and less brilliant colours.

Inkjet printing was also investigated (see Section 3.2.1.). Although inkjet printing can handle several types of dye, only the reactive dyes are suitable for the applicant (cfr Section 2.1). By this limitation, the colour range for deep brilliant colours is reduced even more. Two-sided printing technique has been tried, but was unsuccessful because of the misfit between back and front of the cotton cloth at high speed. The misfit is related to the lack of dimensional stability of the cloth, which makes it impossible to position the cloth such that there is an exact fit between back and front. The double sided inkjet printing technology on cotton is at present fairly slow and at least 43 machines have to be installed to obtain the required capacity. The associated investment cost is about 25 mio €, with a significant higher operating cost compared to the current technology.

<u>Conclusion:</u>

Direct printing techniques do not offer the same versatility and yield an inferior product. Randomness, crackle lines, front and back matching and a large colour range with deep brilliant colours cannot be achieved with any of these techniques.

It is technically not feasible with direct printing techniques to obtain the same product as the current Vlisco products.

4.5.3. Economic feasibility

Only the economical feasibility of RSP is investigated. The inkjet technology does not provide any advantage to Vlisco compared to the RSP technology and requires an even larger investments, operational costs and more space due to the high number of required machines.

The following additional costs, associated with the implementation of these alternatives are considered:

- Capital cost
- Reduced margin

Costs associated with the remaining book value of the equipment, which is replaced, is not taken into account.
The following assumptions and parameters are adopted:

- Base period for calculating PV is 2016, calculated over the period 2016-2034. – This is longer than the period used for appraisal in the SEA, which is based on the decision horizon for authorisation decisions, and better reflects Vlisco's investment cycle in relation to these types of investments

- Discount rate is 10% - This is higher than the 4% discount rate mentioned in the ECHA SEA guidance, which is used in the SEA for this application, and reflects the higher cost of capital faced in the commercial sector compared with the societal perspective adopted in the SEA

- Constant fabric production volume over the assessment period; same as for 2014 (see section 4.1.3.)

4.5.3.1 Capital cost

As set out in section 4.5.2. the following main investments are to be considered:

  - Purchase and installation of additional RSP equipment

The investments costs were estimated based on budget prices for main equipment, standard engineering cost estimation for minor equipment and taking into account an installation factor (to cover insulation piping, instrumentation, etc). The applicant knows the RSP technology. The CAPEX estimate is based on budget prices of existing equipment. Details are provided in the Table 25 below:

Table 25: Breakdown of investment costs of Alternative 1.5[84]

Type of cost	Description	Cost estimate (€million)
New Equipment	Additional RSP printers	[redacted]
Installation	Installation factor 0,3	[redacted]
Contingency	This is ~10% of the budget mentioned in the sub-projects, for unknown expenses that may arise. It is good practice to avoid "optimism bias" by allowing contingency for unspecified risks[xxxii].	[redacted]
Engineering and Project management support	Vlisco are not able to internally manage a project this size Estimated Engineering and project management is 10% of equipment and installation cost	[redacted]
Total		[redacted]
	PV	[redacted]

Note

1. Equipment estimate is done on the basis of budget quotes
2. The installation factor is related to the complexity of the construction and is estimated as a percentage of the equipment cost. The installation a few large and expensive pieces of equipment, is typically in proportion to the cost of the equipment less expensive. The factor has been adjusted from 0.6 to 0.3 for this reason
3. Less engineering costs are estimated for this case because of the lower complexity of the project.

Insufficient capacity is available today for RSP at Vlisco. Such equipment needs to be ordered. Delivery time of 9 months is expected. It was estimated that it takes about 1 year before this equipment can be available for production.

4.5.3.2 Reduced margin

As discussed in the section of technical feasibility, these direct printing techniques lead to a different completely product from the Real Dutch Wax fabrics Vlisco currently manufactures. The product obtained with these techniques is similar to the product already placed on the market by the Asian competition typically using RSP.

[xxxii] HM Treasury (2003) - THE GREEN BOOK Appraisal and Evaluation in Central Government - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

This kind of product is significantly different from the culturally embedded product now made by Vlisco. The typical designs features are directly linked to the historical use of wax and are absent in these alternative products. There is a small but consistent niche market for these wax-based products to be worn at special occasions by a large section of the population in West Africa. The exclusivity of the product is not only supported by the name and fame of the product, which stands for exclusive designs, but most of all by the specific characteristics of the product. A product without these characteristics cannot support this exclusivity and will be valued as a simple commodity product.

The sales prices for these products from the Asian competition are about 1-2 €/yard (see SEA table 2.1). This can be compared with the production cost in Helmond for this kind of material. Although Vlisco's existing Java product, also made with RSP techniques, is sold at higher price ([redacted][85]; SEA table 2.3), this is only sustainable in the context of co-branding with the higher-end, Real Dutch Wax product. If the high-end product disappears from the market, it will no longer be possible to sell the Java fabrics at a premium price compared with the competition. In other words, a move to full RSP production (or a product made by similar technology) mean it will only be possible to sell Java (and the RSP replacement for wax) at a price similar to the competition. Given a unit cost of production for Vlisco's (RSP) Java product of around [redacted][86] (based on McKinsey (2014)), production could no longer be sustained in Helmond at these prices.

Vlisco-Group started in 2007 the introduction of a product based on printed bubbles but with other key features such as indigo, half tones and micro cracks still present. Even then, the result was a [redacted][87] decrease in sale price . This evidence has been used as the basis for an estimation of the financial impact of adopting RSP which, has none of the key features, as a production technology for Real Dutch Wax in place of the existing resin-based technology. It has been assumed that, following the replacement of the existing resin-based technology with an RSP technique, prices for both the Real Dutch Wax product and the Java product would fall by 35% per year until they reach a level currently charged for comparable Chinese printed fabrics (€1.95, which is actually at the upper end of this market), after which prices are assumed to remain constant. These prices are then compared with Vlisco's current average cost of producing RSP-based Java fabrics (which reflects how much it will cost to produce Real Dutch Wax-style fabrics using RSP). The difference between the sales price and the unit production cost 'pre-RSP' and 'post-RSP' then gives an estimate of the profit made in each year following the introduction of these change.

The results of this simulation are presented in Table 26. The effect on the 'Real Dutch Wax' price in the first year after implementation is not sufficient to make production uneconomic compared with the cheaper production cost using the RSP technique. However, the assumed reduction in the price of the Java fabric does result in losses in that year. In the following year (2018), predicted prices for both 'Real Dutch Wax' and Java are below costs of production. Prices for Real Dutch Wax fell further in the following year until stabilising at the assumed Chinese-equivalent price of €1.95 per yard. The present value of the reduction in margin over the 2016-2034 period, compared with the margin which would be realised if existing market conditions were maintained, is just under [redacted][88].

Table 26: Impacts on profits of the introduction of Alternative 1.5[89]

	2016	2017	2018	2019-2034
Real Dutch Wax price	[redacted]	[redacted]	[redacted]	[redacted]
Real Dutch Wax cost	[redacted]	[redacted]	[redacted]	[redacted]

Margin	[redacted]	[redacted]	[redacted]	[redacted]
Total margin	[redacted]	[redacted]	[redacted]	[redacted]
Real Dutch Wax volume	27,279,000	27,279,000	27,279,000	27,279,000
Margin change (compared with 2016)	[redacted]	[redacted]	[redacted]	[redacted]
Java price	[redacted]	[redacted]	[redacted]	[redacted]
Java cost	[redacted]	[redacted]	[redacted]	[redacted]
Margin	[redacted]	[redacted]	[redacted]	[redacted]
Java volume	[redacted]	[redacted]	[redacted]	[redacted]
Total margin	[redacted]	[redacted]	[redacted]	[redacted]
Margin change	[redacted]	[redacted]	[redacted]	[redacted]
Total margin change (compared with 2016)	[redacted]	[redacted]	[redacted]	[redacted]
Total present value cost				[redacted]

4.5.3.3 Conclusion on economic feasibility of Alternative 1.5

Based on the preceding discussion, the estimated costs of implementing a RSP alternative for Use 1 (and Use 2) are [redacted] [90]in present value terms over the 2016-2034 period (discounted at 10%).This is almost entirely made up of the losses incurred as a result of price reductions following the move away from the traditional Real Dutch Wax technique to one comparable with standard Chinese printed products. These losses would inevitably lead to the closure of Vlisco's textiles business.

The conclusion is that the alternative to switch to RSP for Use 1 (and Use 2) is currently not economically feasible

4.5.4. Risk reduction potential

These processes are largely solvent free and can be considered as a reduction of risk.

4.5.5. Availability

The technology of RSP is available and known to the applicant. Several types of direct printing machines are available on the market, all with the limitations mentioned above. A machine providing the same product quality as the current process is not available.

The technology of inkjet printing is available and known to the applicant. Technology to provide a two-sided matching design for cotton at comparable speed as RSP, based on inkjet is not available on the market.

4.5.6. Conclusion on suitability and availability for Alternative 1.5

The applicant does not consider direct printing as a suitable alternative. None of these techniques yield the same product as the current product; the alternative is technically not feasible. The differences in product are crucial for the product look, and cannot be removed without affecting the market value. Selling these products at a lower price is not viable with the production costs at Helmond. As such the alternative is economically not feasible.

4.6. ALTERNATIVE 1.6: Switchable Solvent

4.6.1. Substance ID and properties

Switchable solvents[xxxiii] is a technology by which the solubility characteristics of the solvent system can be reversibly manipulated (the so-called “switch”). This is done via the introduction or removal of carbon dioxide. In the absence of CO_2 the switchable solvent behaves like a traditional, low polarity, organic solvent. On exposure to CO_2 and in the presence of water, the solvent becomes hydrophilic and water miscible. Removal of the CO_2 from the system causes the switchable solvent to revert to its hydrophobic form that is again immiscible with water. The main advantage of this technology is that dissolved material can be separated from the solvent without applying heat. In literature[xxxiv] these solvents are known as Switchable Hydrophobicity Solvents (SHS).

In appendix F an example is provided of this technology.

4.6.2. Technical feasibility

The technical feasibility of the technology has been proven in various applications. However, this technology has yet to be developed for resin. A main advantage of this technology is the fact that it is based on an extraction technology which provides an increased likelihood that the current product look and feel can be maintained compared to some other alternatives.

Because it is solvent-based technology, it has the potential to be an alternative for both Uses 1 and 2. In Figure 12 the concept for the use of switchable solvents for extraction is shown.

[xxxiii] http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-$5.48-million.php

[xxxiv] “Alternative Solvents for Green Chemistry Second Edition RSC Publishing 2013, F.M. Kerton and R. Marriott

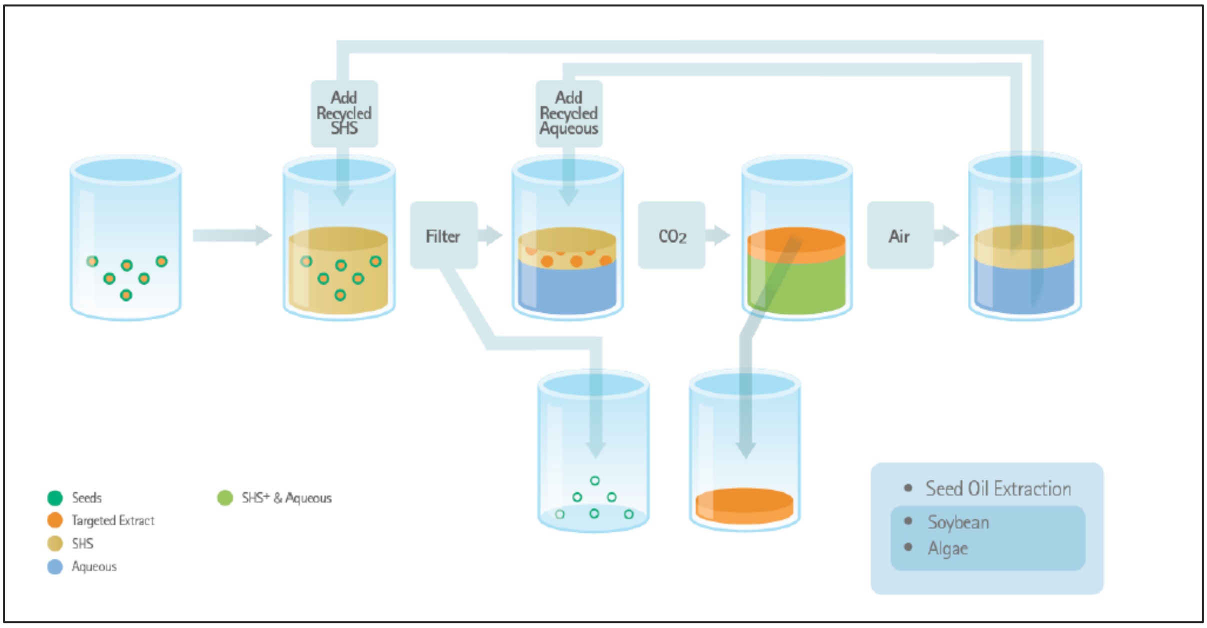

Figure 12: Switchable Solvent used in extraction applications (figure 3 in Appendix D)

Although the concept is proven for other applications, several major research topics still need to be investigated to assess the technical feasibility of this alternative. This is described in the long-term development plan for this alternative (see 4.6.2.1).

The development time for this alternative has been estimated at 12 years. This timing takes into account that Vlisco has extensive experience with extraction processes but no experience whatsoever with switchable solvents. The technology of switchable solvents is very innovative and collaborations with research institutes are being set up. As such, 12 years could be regarded as a minimum time for adoption.

4.6.2.1 Long-term development plan

The long-term development plan is based on the standard working procedures that are used at Vlisco for execution of R&D and engineering projects.

The start date of the project is the date of EU COM decision of a granted authorisation. In practice, this can be prior to the Sunset Date. At that point in time, all pre-engineering to prepare for the non-use scenario will be stopped and the long-term development plan will start.

The multi-year development plan (Figure 13) is needed for the detailed planning of all R&D activities required.

[redacted]

Figure 13: Switchable Solvent long-term development plan[91]

A break-down for a long term development plan for this alternative is provided in Table 27.

Table 27: Switchable Solvent long-term development plan[92]

Alternative for Use 1&2: Switchable solvent		Per step	Total (Years)
1.	Set up contracts with development partners	[redacted]	[redacted]
2	Long list of possible solvents	[redacted]	[redacted]
	Literature study		
	Lab scale tests		
3	Pilot tests with selected solvent	[redacted]	[redacted]
4	Concept for the process	[redacted]	[redacted]
	Technical concept		
	Cost calculation		
5	Basis of design and approval	[redacted]	[redacted]
Milestone: Approval for design & budget			
6	Basic design of the different process steps	[redacted]	[redacted]
7	Detailed design	[redacted]	[redacted]
8	Equipment selection	[redacted]	[redacted]
Milestone: Approval for construction			
9	Procurement (long lead items)	[redacted]	[redacted]
10	Construction	[redacted]	[redacted]
Milestone: Construction done			
11	Start-up	[redacted]	[redacted]
Milestone: Start-up finished			
12	Introduction into the market	[redacted]	[redacted]
13	Optimization	[redacted]	12
Milestone: Commercially available			

These are timings are subject to significant uncertainty, and assume that all milestones are met and integrate seamlessly. However, the large number of steps means that there are many potential sources for delay, and delays earlier in the programme will have knock-on effects further along the implementation. Therefore, there is scope for the programme duration to be considerably longer than 12 years.

The development plan is an integrated plan for both Use 1 and 2. The optimal situation is one in which the alternative is suitable for both uses. As such, parts of the installation can be common, similar to the situation in the existing installation. This leads to an optimization of usage of installation and thus an optimization of cost.

The different steps of the development program are explained in Table 28:

Table 28: Stepwise approach for research, engineering and implementation of switchable solvents[93]

Step	Detail
1	[redacted]
2	[redacted]
3	[redacted]
4	[redacted]
5	[redacted]
6	[redacted]

Step	Detail
	[redacted]
7	[redacted]
8	[redacted]
9	[redacted]
10	[redacted]
11	[redacted]
12	[redacted]

4.6.2.2 Conclusion

The technical suitability of SHS as an alternative to the use of TCE has not been proven. Significant development work is still needed. Currently the development is estimated to take at least 12 years, but given the uncertainty there is scope for this to be much longer.
Given the similarity to the current process technology – i.e. extraction of the resin – the chance that the product image (look & feel) will be similar, is very likely. Also the extraction process in Use 2 can be similar. Therefore, this new technology has been identified by the applicant as a technology of very high, long-term potential.

4.6.3. Economic feasibility

The following additional costs, associated with the implementation of this alternative are considered:

- Capital cost
- Operational cost
- Costs associated with downtime

Costs associated with the remaining book value of the equipment, which is replaced, is not taken into account.

The following assumptions and parameters are adopted:

- Base period for calculating PV is 2016, calculated over the period 2016-2034. – This is longer than the period used for appraisal in the SEA, which is based on the decision horizon for authorisation decisions, and better reflects Vlisco's investment cycle in relation to these types of investments

- Discount rate is 10% - This is higher than the 4% discount rate mentioned in the ECHA SEA guidance, which is used in the SEA for this application, and reflects the higher cost of capital faced in the commercial sector compared with the societal perspective adopted in the SEA

- The resin removal from the cloth with switchable solvents will be available at the same time as Use 2 with switchable solvents

- Constant fabric production volume over the assessment period; same as for 2014 (see section 4.1.3.)

- Because of the very uncertain technical feasibility of this option, the costs of and time for implementation are subject to a wide margin of error. However, they are based on best currently available information and therefore represent the most appropriate basis for investment appraisal.

4.6.3.1 Capital cost

This alternative is still in a very conceptual stage. No details on the installation are available yet. The estimate of the capital cost is based on the solvent free extraction for Rosin alternative, being the highest investment expenditure with the exception of the flammable solvent. The latter is more expensive because the required adaptations of existing equipment for ATEX. The overall complexity of the process and the equipment is estimated of the same level as solvent free extraction.

The following main investments are required:

- Installation for recovery of resin out of breaking-off water with a switchable solvent

The investment costs were estimated based on estimated prices for main equipment, standard engineering cost estimation for minor equipment and taking into account an installation factor (to cover insulation piping, instrumentation, and so on). Details are provided in the Table 29 below:

Table 29: Breakdown of investment costs of Alternative 1.6[94]

Type of cost	Description	Cost estimate (€million)
New Equipment	Estimated on the basis of a first rough design of the potential process	[redacted]
Installation	Installation factor 0,6	[redacted]
Contingency	This is ~10% of the budget mentioned in the sub-projects, for unknown expenses that may arise. It is good practice to avoid "optimism bias" by allowing contingency for	[redacted]

Type of cost	Description	Cost estimate (€million)
	unspecified risks[xxxv].	
Engineering and Project management support	Vlisco are not able to internally manage a project this size Estimated Engineering and project management is 20% of equipment and installation cost	[redacted]
Total		[redacted]
	PV	[redacted]

Note

1. Installation factor: factor used to estimate the cost of construction based on the cost of the equipment. This factor depends on complexity of the installation. The factor was established by an engineering company "IV industries" in a report prepared for Vlisco.

4.6.3.2 Operational cost

This estimate is made with following assumption:

- Overall resin recovery rate is similar as present (95%)
- Overall solvent recovery rate similar as present (>99%)
- Headcount to operate the installation is as current
- No solvent evaporation

A constant headcount is assumed since the process is expected to be similar to the current solvent process. This should allow a similar level of automation and integration.
The current energy cost for the TCE based process is [redacted] [95]€. The three main current processes with high energy consumption are the resin distillation, water stripper and the air treatment (active carbon system). There will be no resin distillation in the process with switchable solvents. Also for the air treatment a lower energy consumption is expected. As a result, the energy use in the future process is estimated to drop to 25% of the current use. This represents a yearly saving of [redacted] [96]€.

4.6.3.3 Downtime Costs

It is estimated that the project will be available for production at the earliest 12 years after Sunset Date. In the period between Sunset Date and completion of the project, Vlisco will not be able to produce any wax-based product. This will result in a significant loss of sales in that period.

The same argumentation and methodology as in section 4.2.3. can be applied here.

Table 30: sets out the estimated loss to Vlisco over this period (May 2016 to end 2034)

[xxxv] HM Treasury (2003) - THE GREEN BOOK Appraisal and Evaluation in Central Government - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

Table 30: Cost of downtime for Alternative 1.6[97]

Switchable Solvent	(€ million)					
	2016 (6 months)	2017-2025	2026	2027	Total	Total (PV)
Lost profit	[redacted]	[redacted]	[redacted]		[redacted]	
One time costs	[redacted]		[redacted]	[redacted]	[redacted]	
Downtime Costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Notes:

1. Figures have been rounded to nearest whole number to avoid false accuracy

4.6.3.4 Conclusion on economic feasibility of Alternative 1.6

Table 31 summarizes the preceding discussion and presents the estimated costs of implementing the switchable solvent alternative for Use 1. The total present value cost over the period 2016-2034 is estimated to be around [redacted][98] (discounted at 10%) for Use 1. By far the largest proportion of this cost is the estimated loss of profit due to the need to cease production during the very long (at least 12 year) expected implementation period (and, as discussed, lost profit probably underestimates the true costs of temporary closure to the company). There would also be costs associated with the required new capital investment. However, there are expected savings in operational costs, due to lower energy consumption, but these benefits are minor in comparison with the costs of the alternative.

The conclusion is that the alternative to adopt a switchable solvent for Use 1 (and Use 2) is currently not economically feasible.

It is, however, worth noting that this option has the potential to be economically feasible, due to expected savings in energy consumption. The current infeasibility is due to the very long implementation time and the associated need to cease Vlisco operations during this period, with associated losses in profit. However, if these losses could be avoided (as would be the case in the event of authorisation, for instance), the net present value cost of this option would be reduced to €5.0m. With efficiencies in implementation costs and a shortening of the implementation time, it is possible that this option could approach economic feasibility, although the implementation period is still expected to be significant.

Table 31: Overview costs Alternative 1.6[99]

Switchable solvent to dissolve resin from cotton cloth		
Implementation time	12 years	- Development of technology - Design and building of installation - Testing and start-up
Investment cost (PV)	[redacted]	- New equipment and installation of equipment
Impact on OPEX (PV)	[redacted]	- Reduction of energy cost, no effect within the period 2016-2027

Switchable solvent to dissolve resin from cotton cloth		
Transition cost (PV)	[redacted]	- No production of wax product during 12 years
Total (PV)	[redacted]	

4.6.4. Risk reduction potential

It is not possible to assess the overall reduction of risk, as the solvent itself still has to be identified, but known switchable solvents are less hazardous compared to TCE. Switchable solvents have the potential to reduce the carbon footprint of the process through the reduction of energy consumption.

4.6.5. Availability

The technology of switchable solvents is not available to the applicant. A collaboration program will have to be set up with research institutes and/or licence holders to develop this technology for this Use. Discussions are on going with GreenCentre Canada (see section 3.2)

4.6.6. Conclusion on suitability and availability for Alternative 1.6

The applicant does not consider this alternative as suitable. Significant development work is still required to make this alternative technically suitable. This alternative has been included in the long-term development plan because of the potential of having a lower OPEX and yielding the same product image.

5. OVERALL CONCLUSIONS ON SUITABILITYAND AVAILABILITY OF POSSIBLE ALTERNATIVES FOR USE 1

5.1. ALTERNATIVES for Use 1

Based on the information and analysis presented in Sections 3 and 4, the applicant has made estimates of the total costs of adopting the different alternatives to the use of TCE after the Sunset Date in 2016.

Estimates have been made for the adoption of alternatives for Use 1 and Use 2. However, as previously discussed, the choice of alternatives for each use is interdependent. This section presents estimates of the costs of adopting potential combinations of alternatives for Uses 1 and 2, based on their potential (combined) technical feasibility. Technical feasibility is a prerequisite for economic feasibility, although there are potentially tradeoffs between the two measures.

Estimates are made on the basis of best current knowledge. Some of the alternatives are considered potentially more viable than others, and as a result, their implementation requirements, and hence their costs, can be estimated with more confidence. Other alternatives are thought to be less technically feasible and hence had not been investigated or developed to the same extent. The costs of all options are therefore subject to varying degrees of uncertainty; cost estimates would need to be improved as part of any implementation plan. However, the current estimates can be considered the best available for appraisal and planning purposes at the current time.

Estimates are presented in net present value terms, over the period 2016-2034. This is a period that typically is taken for large capital projects. The discount rate used is 10%. This is higher than the figure of 4% suggested in the ECHA SEA guidance, reflecting the higher cost of capital relevant to investment appraisal from the applicant's private (rather than social) perspective. The resulting estimates are presented in Table 32. A second set of calculations was done and is used in the SEA, with the 4% discount rate and an evaluation period equal to 12 years, which is the suggested duration of a 'long' review period for an authorisation and hence represents an appropriate decision timeframe for the SEA. The ranking and the overall conclusions remain the same.. The resulting estimates are presented in Table 32

Table 32: Cost (PV) adopting alternatives to the use of TCE[100]

Option for Use 1 and Use	Use 1 (mio €)	Use 2 (mio €)	Total (mio €)
PERC PERC	[redacted]	[redacted]	[redacted](94%)
PERC solvent free extraction	[redacted]	[redacted]	[redacted](100%)
Flammable solvent Flammable solvent	[redacted]	[redacted]	[redacted](101%)
Flammable solvent solvent free extraction	[redacted]	[redacted]	[redacted](112%)

Option for Use 1 and Use	Use 1 (mio €)	Use 2 (mio €)	Total (mio €)
Rosin solvent free extraction	[redacted]	[redacted]	[redacted] (110%)
Switchable solvent Switchable solvent	[redacted]	[redacted]	[redacted](109%)
RSP			[redacted](244%)

Note

1. The base period is 2016 for calculating PV using a discount rate of 10%.
2. PV is calculated over the period 2016-2034
3. Total costs for the option for Use 1 and Use 2 are provided relative to the cost of the most likely option in case the use of TCE would no longer be allowed after sunset date.

It can be seen from Table 32 that a switch to RSP is estimated to be by far the most costly option, with a net present cost of [redacted][101] € over the 2016-2034 period. This estimate reflects the fact that a move to screen printing would remove the unique physical design characteristics currently possessed by Vlisco products. This in turn is expected to result in a drop in price for both Vlisco's Real Dutch Wax and Java fabrics (the latter currently earning a premium over comparable products produced in China, due to its association with the high-end Real Dutch Wax product in Africa). Evidence suggests these price reductions would happen rapidly following the switch to a more standard printed fabric, with prices ultimately falling to levels comparable to those currently earned by equivalent Chinese products. These prices are below the current unit production costs of Vlisco's printed (Java) fabrics, and hence this option is associated with significant financial losses which would ultimately be unsustainable and would result in the closure of Vlisco's business.

The options based on the adoption of flammable solvents (with or without solvent free extraction), rosin with solvent free extraction, and switchable solvents are all estimated to generate costs of between [redacted] €[102] over the 2016-2034 period. The greater proportion of these costs in each case is accounted for by the Use 1 alternative. In turn, this reflects the long implementation periods predicted for these options. These implementation periods are shown in Figure 14.

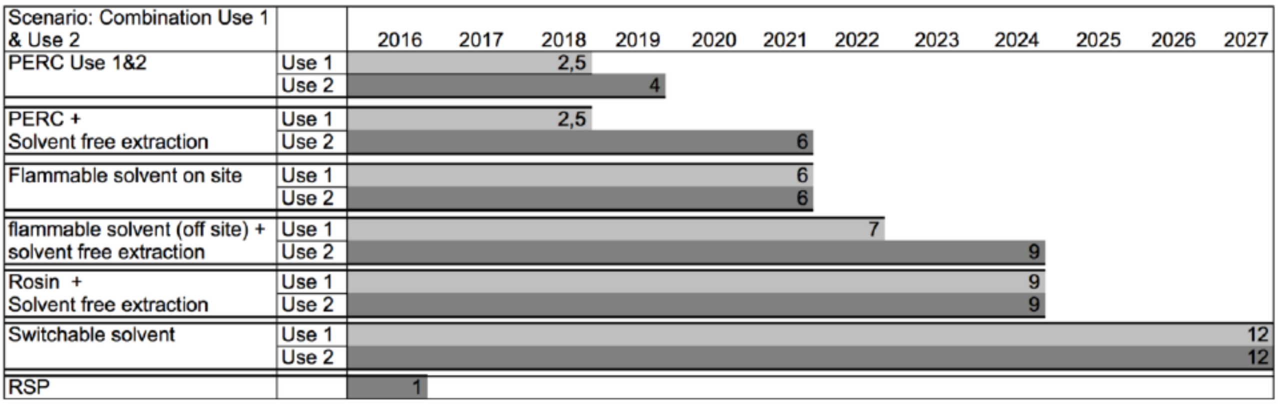

Figure 14: Best case implementation periods for combinations of options:

Whereas implementation of Use 2 alternatives after the TCE Sunset Date can be dealt with by increasing the net consumption of resist, the inability to implement Use 1 before the Sunset Date necessitates complete shutdown of Vlisco's Real Dutch Wax production operation. This would result at a minimum in the loss of profits for each year closure is necessary – estimated at around [redacted][103] (in 2014 terms), which serves to emphasise the importance of implementation times to the overall cost of alternatives to TCE for Use 1. In addition, there would be costs associated with redundancy of permanent staff, and then rehiring and training prior to (re-)start-up, as well as testing the new processes and returning the installation to an commercial operational basis. Costs associated with mothballing the plant are not included in the estimates, which assume that sales will return to pre-closure levels even after an absence of the market of 12 years (and possibly longer). There is a risk that the market would never return to its previous level, and might even effectively disappear. The costs of these options which include (in some cases significant durations of) closure are certainly underestimated, therefore, and possibility significantly.

The costs of the 'PERC' and 'PERC + solvent free extraction' are consequently lower, at between [redacted][104]. These estimates reflect the relatively short times for implementation of PERC-based alternatives for Use 1. However, both involve implementation after the TCE Sunset Date, and hence costs are still large in absolute terms due to the loss of profit associated with the need for temporary shutdown. In addition, the shorter shut-down period means that it would not make sense to make permanent staff redundant, only to have to rehire and (possibly) retrain them only months later, so Vlisco would propose to retain permanent staff even during production shut-down. Although this would avoid any social costs associated with redundancy, it significantly increases the costs of the PERC options in the short term.

Nevertheless a PERC-based option for Use 1 (with PERC or solvent free extraction for Use 2) is clearly the least cost alternative to TCE compared with the other alternatives available. As a result, PERC would be the option which Vlisco would adopt for Use 1 if it could no longer use TCE after the Sunset Date (i.e. the non-use scenario in the event that authorisation is refused). Indeed, plans have already been initiated to adopt PERC for Use 1 in an attempt to minimise its implementation period and thereby reduce its costs.

The choice of alternative for Use 2, in combination with PERC for Use 1, is not subject to such urgent timescales. The cheaper option is estimated to be the adoption of PERC also for Use 2. However, as discussed above, PERC is subject to significant regulatory uncertainty due to (*inter alia*) its potential to be included into Candidate List, as it fulfils several of the criteria mentioned in the SVHC Roadmap 2020. PERC is also mentioned in the EU COM dbase as an EDC, Cat 2. Since the criteria for EDC are under development still, risks and mitigation thereof can currently not be assessed. PERCs hazard and risk profile is also not consistent with Vlisco's long-term aim of substituting away from the use of hazardous solvents in the production of its printed fabrics. As a result, Vlisco proposes to adopt solvent free extraction as the alternative to TCE for Use 2, even though this is expected to cost more (due largely to higher resist consumption associated with the longer implementation times) than a PERC-based option. The total present cost of the PERC + solvent free extraction option is estimated to be [redacted][105] over the period 2016-2034. This is the cost of the non-use scenario which is taken forward (after adjustment for the social perspective) to the SEA for comparison with the risks of continued use of TCE.

The cost of the switchable solvent option is estimated to be just over [redacted]€[106] is present value terms over the period 2016-2034. This makes it the third most costly option of all those considered in this analysis. The high cost reflects the long implementation period expected with this option – it is predicted that implementation could only occur at least 12 years after the Sunset Date for TCE, due to the significant technical uncertainties which would need to be resolved for this option to be feasible. In the absence of authorisation to continue to use TCE during this period, this would mean Vlisco would have to cease operations for a minimum of 12 years, with associated loss of profit. This option is clearly not economically feasible or affordable under these circumstances. However, as discuss in Section 4, the switchable solvent alternative is the only option which is considered to have the potential to result in a net reduction in operating costs (due to reduced energy consumption) following transition. The net present value of the option, if it could be adopted without the need for downtime (e.g. in combination with a positive authorisation decision or a PERC-based option) would be relatively low, compared with the other options, at around 5 mio €. These costs (although very uncertain) might fall further if implementation periods could be shortened, meaning that the investment at least in principle could become economically feasible from Vlisco's perspective. As a result, Vlisco intends to investigate switchable solvents as a long-term means to substitution away from solvent-based processes.

5.2. Action Plan

In 4.6.2.1, a description is provided of a long term development plan for an alternative to TCE (see Figure 15). This action plan will be initiated as soon as the final decision on the AfA is communicated. Until then, the pre-engineering of the non-use scenario will be continued.

[redacted]

Figure 15: Switchable Solvent long-term development plan[107]

APPENDIX A: OVERVIEW KNOWLEDGE DOCUMENTS TCE ELIMINATION

Author: T. Hofs

[redacted].[108]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]					
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]					
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
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APPENDIX B: ALTERNATIVE SOLVENTS

Based on the physical properties, internal investigations and supplier's information, solvents are selected. The key properties are listed in Table 5 and Table 6

List of solvents[109]

Solvent	CAS no.	Equivalent Solublity speed	Solubility in water	Flammability °C	Boilingpoint °C	Density
highly refined hydrocarbon, (tetrapropaan) C10-C13	68551-17-7	[redacted]	0	57	200	0,75
highly refined hydrocarbon,(kerosine)	64742-47-8	[redacted]	0	66	175	0,82
1,1,1 Trichloorethaan	71-55-6	[redacted]	1,4	non	74	1,32
1,1,2 Trichloorethaan	79-00-5	[redacted]	4,5	non	110	1,43
1 4-Dioxane	123-91-1	[redacted]	miscible	12	101	1,03
2,2,2-trifluorethanol	75-89-8	[redacted]	miscible	29	74	1,39
2,2,4 trimethylpentane (iso-octaan)	540-84-1	[redacted]	0	-12	99	0,7
broombenzene	108-86-1	[redacted]	0,4	51	156	1,5
Butanon / Methyl Ethyl Keton	78-93-3	[redacted]	275	-9	80	0,81
Cycloheptane	291-64-5	[redacted]	0	6	118	0,81
Cyclohexane	110-82-7	[redacted]	0	-20	81	0,78
Cyclohexanon	108-94-1	[redacted]	90	44	156	0,95
Cyclooctane	292-64-8	[redacted]	0	30	149	0,83
decamethylcyclopentasiloxane	541-02-6	[redacted]	0	76	210	0,96
Decane	124-18-5	[redacted]	0	46	174	0,73
Di-basic ester Diisobutylester DIB		[redacted]	1	144	280	0,96
Di-basic ester IRIS	14035-94-0	[redacted]	22	98	222	1,05
dibutoxymethane	2568-90-3	[redacted]		60	180	0,84
Dichloromethane / Methyleen chloride	75-09-2	[redacted]	13	non	40	1,33
dipropylene glycol tert-butyl ether	132739-31-2	[redacted]	120	114	264	0,9
DOWANOLTM DPM Dipropylenglycolmethylether		[redacted]	miscible	75	180	0,95
DOWCLENE 1601 modified alcohol		[redacted]	63	63	175	0,83
DOWCLENE* 1611 modified alcohol		[redacted]	miscible	79	190	0,94
EcoSolve (c10-C13 isoalkaan)	68551-17-7	[redacted]	0	61	200	0,76
Ethyl ethanoate, ethyl acetate, C4H8O2	141-78-6	[redacted]	83	-4	77	0,9
Highsolve E 99 (1,1,2,,2-tetraethoxyethane	3975-14-2	[redacted]	45	71	196	0,92
Highsolve P alcohol acetal		[redacted]	miscible	47	155	1,01
Limonene/1-Methyl-4-(1-methylethenyl)-cyclohexene	138-86-3	[redacted]	14	50	176	0,84
MCS-2806 Process Fluid Eastman /Exxsol D180 nafta		[redacted]	0	75	192	0,76
Methyl Isobutyl Keton (MIBK)	108-10-1	[redacted]	19,1	14	117	0,8
Methylcyclohexane	108-87-2	[redacted]	0	-3	101	0,77
Methylcyclopentane	96-37-7	[redacted]	0	-10	72	0,78
monochlorobenzene	108-90-7	[redacted]	0,4	29	131	1,11
n- octane	11-65-9	[redacted]	0,01	13	125	0,7
N-broom propane,	106-94-5	[redacted]	2,5	22	71	1,35
N-Butyl propinate	590-01-2	[redacted]	2	100	145	0,88
Nebol oderless		[redacted]	0	63	195	tbd
n-Heptane C7H16	142-82-5	[redacted]	0,003	-4	98	0,68
n-hexane C6H14	110-54-3	[redacted]	0,01	-26	69	0,65
Nonane	111-84-2	[redacted]	0	31	150	0,72
Novec HFE-72DE (HFE & azeotrope t-1,2dichloorethylene	156-60-5 + 163705-05-4	[redacted]	< 10 ppm	non	43	1,28
Oxolane / tetrahydrofuraan	109-99-9	[redacted]	miscible	-14	66	0,89
Pentaan	109-66-0	[redacted]	0,04	-49	36	0,63
Perchloroethylene	127-18-4	[redacted]	0,15	non	121	1,62
propanon /Aceton, C3H6O	67-64-1	[redacted]	miscible	-17	56	0,79
Super Critical CO2:		[redacted]	0	non	-90	
tetrahydrofurfuylalcohol	97-99-4	[redacted]	miscible	74	178	1,1
Toluene, methylbenzene, C7H8	108-88-3	[redacted]	0,47-0,52	6	111	0,87
Trichloroethylene	79-01-6	[redacted]	1,1	non	87	1,46
Trichloromethane	67-66-3	[redacted]	8	non	61	1,48
Vetrel SDG Decafluorpentane t-1,2DCE	156-60-5 +138495-42-8	[redacted]	tbd	non	43	1,29
Zeorora-H Hepta fluor cyclo pentane	15290-77-4	[redacted]	0,72	non	83	1,58

APPENDIX C: VLISCO FABRICS VS. FABRICS MADE WITH SCREEN PRINTING

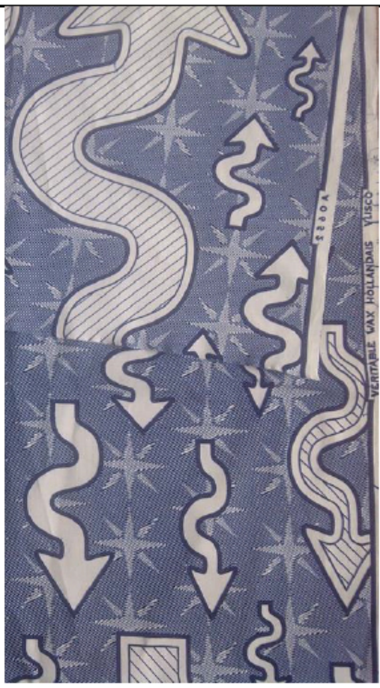
Vlisco has been operating since 1846 and over time refined/improved the quality of the product and the process. It is important to illustrate some of these key design features made possible by using a wax process and TCE compared to other techniques such as screen printing. Currently, it is not possible to replace TCE and/or resin without compromising the quality of the products being produced.

Key Vlisco design features

- Designed indigo dyeing
- Broad colour range; vivid and bold colours (reactive, azoic and phtalogene dye)
- A controlled matching of front and back: same colour or half tones colours
- Non repeating unique bubbling patterns
- Fine hair crackles
- Bleeding, i.e. soft lines, blurred edges

Table 33 sets out the criteria for technical feasibility to create the same end product and which are related to the use of TCE. These differences enable Vlisco to differentiate themselves with the majority of prints sold on the market using RSP or other printing techniques.

Table 33: Key Vlisco design features for customers[110]

Key features	Illustration	Basic description
Substrate		Cotton, for wear comfort in tropical area's
Designed indigo dyeing		**Desirable effects for consumers** Indigo has a large cultural significance in many African countries and has been used in African cloth-making since the 16th century. **What is it and how is it created?** Indigo is the deep rich colour and is difficult to apply because of the chemistry. Indigo is applied to the cloth, printed with a resin design, by multiple dipping in dye baths. Due to the used resin resist and dyeing technique there is no difference in image on both sides of the cloth. A large part of the Vlisco products are dyed with Indigo as base colour. **Relationship with TCE** [redacted]
Broad colour range		**Desirable effect for the consumers** A wide range of deep and vivid colours with superior properties of resistance to wear (wash, light, rubbing, perspiration). **What is it and how is it created** The colouring of the cloth is typically done in separate steps: a base dyeing step and up to 3 colour fitting steps. Each of these steps can use totally different types of dyes (Indigo, reactive, azoic & phtalogenes). Each dye type requires a specific application- and chemical fixation process. The working method allows the applicant to use a very broad range of colours combined with superior fastness as requested by the customers. **Relationship with TCE** [redacted] The resin requires the use of a solvent to remove the resin completely from the cloth. TCE is a suitable solvent because it is not affecting the colours and the cloth..

Key features	Illustration	Basic description
Matching of front and back		**Desirable features for consumers** The customer is looking for unique design effects on the product. Halftone is such an effect and a sign of the quality of the applicant's wax products. The halftone serves as a mark of authenticity to customers that the wax product is original. **What are half tones and how are they created?** Halftone refers to creating different, yet equally vibrant images [redacted] This can also be used to create different images on both sides of the fabric. **Relationship with TCE** [redacted] The resin leads to the use of a solvent to completely remove the resin from the cloth.
Non repeating unique bubbling patterns		**Desirable features for consumers** The bubbling effect creates an organic, unpredictable, vibrant image matching the cultural heritage of the customer. Vlisco product is recognized by the customer as a high quality product because this unique bubbling effect is related to the design and is different for each yard. Vlisco is nearly the only one able to produce this and functions as a mark or origin and authenticity (i.e. the applicant's design)[xxxvi]. **What is bubbling and how is it created?** [redacted] **Relationship with TCE** [redacted]

xxxvi Elisabeth Hackspiel, 2008. *Modernity and Tradition in a Global World: Fashion in Africa*. *African Arts*, Vol. 41, No. 2 (Summer, 2008), pp. 90-91 http://www.jstor.org/stable/20447889.

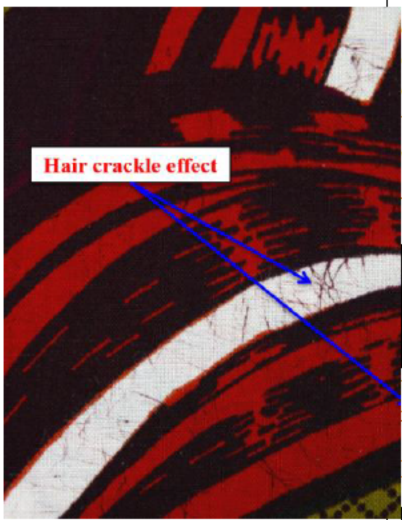
Key features	Illustration	Basic description
		[redacted]
Crackle effect		**Desirable features for consumers** The crackle effect is another effect that creates an organic, unpredictable, vibrant image matching the cultural heritage of the customer. It is also a sign of authenticity; The crackle effect is partly determined by the design and cannot be controlled during the production process. Crackles adds to the applicant's uniqueness, as each design will have differing amounts of crackling. **What is the crackle effect and how is it created?** [redacted] After removal of the resin these cracks appears in the cloth only at positions where the resist was applied **Relationship with TCE** [redacted]
Soft appearance		**Desirable features for consumers** A soft appearance of the design is desired by the consumer. Softer edges of the design are a uniqueness that can best be obtained from traditional and high-quality wax printing processes. **What is the soft design and how is it created?** [redacted]. **Relationship with TCE** The soft edges can only be generated by the combination of dyeing and printing techniques with the use of a resin The resin leads to the use of a solvent to completely remove the resin from the cloth.

Table 34: The differences between a Vlisco wax product and a screen printed product[111]

Feature	Vlisco wax product	RSP or other printing technologies printed product
Designed indigo dyeing	Indigo base colour made by dyeing with resin resist and 9 subsequent dyeing dippings to get the colour dept.	[redacted]
Broad colour range	Combination of Indigo, Azoïc, Phtalogene, mix Azoïc/Phtalogene and Reactive dyes are used. This is possible because the dyes are separately printed/fixed/washed. In this way the colour range of all different dye types can be added. This delivers a much bigger colour range than in case only one dye type can be used.	Only one dye type (Reactive dyes) can be used, because all colours need to be printed and fixed in one process. Mix of dye types is not possible because they have different fixation methods.
Matching of front and back	[redacted]	[redacted]
Non repeating unique bubbling patterns	No repeat of bubbling pattern every yard. [redacted]	Repeat of bubbling pattern every yard. [redacted]
Crackle effect	[redacted]	[redacted]
Soft appearance	[redacted]	[redacted]

APPENDIX D: SWITCHABLE SOLVENTS

Switchable Solutions Inc.

Chemistry for the Future

Switchable Solutions Inc. is revolutionizing manufacturing, chemical and materials production and extraction by redefining the way organic solvents are used. With its suite of *Switchable Hydrophilicity Solvents* (SHS), Switchable Solutions is able to offer industry all of the benefits of organic solvents while at the same time maximizing cost savings, environmental sustainability and human safety.

Representing a breakthrough in organic solvent technology, the solubility characteristics of our solvent systems can be reversibly manipulated, on-demand, via the introduction or removal of carbon dioxide (CO_2). In the absence of CO_2, our SHSs behave like a traditional, low polarity, organic solvent. On exposure to CO_2 and in the presence of water, our solvents become extremely hydrophilic and water miscible. Removal of the CO_2 from the system causes the SHS to revert to its hydrophobic form that is, once again, completely immiscible with water.

Figure 1. Reversible switching of SHS between hydrophobic and hydrophilic forms with CO_2 and water.

The low energy, nominal temperature and pressure manipulation of this breakthrough solvent system can enhance a number of industrial processes including:

- cleaning and remediation;
- extraction;
- isolation from chemical synthesis;
- material recovery in recycling;
- functionalization of materials; and
- encapsulation.

Schematic representations of each of these application categories are presented in Figures 2 to 7.

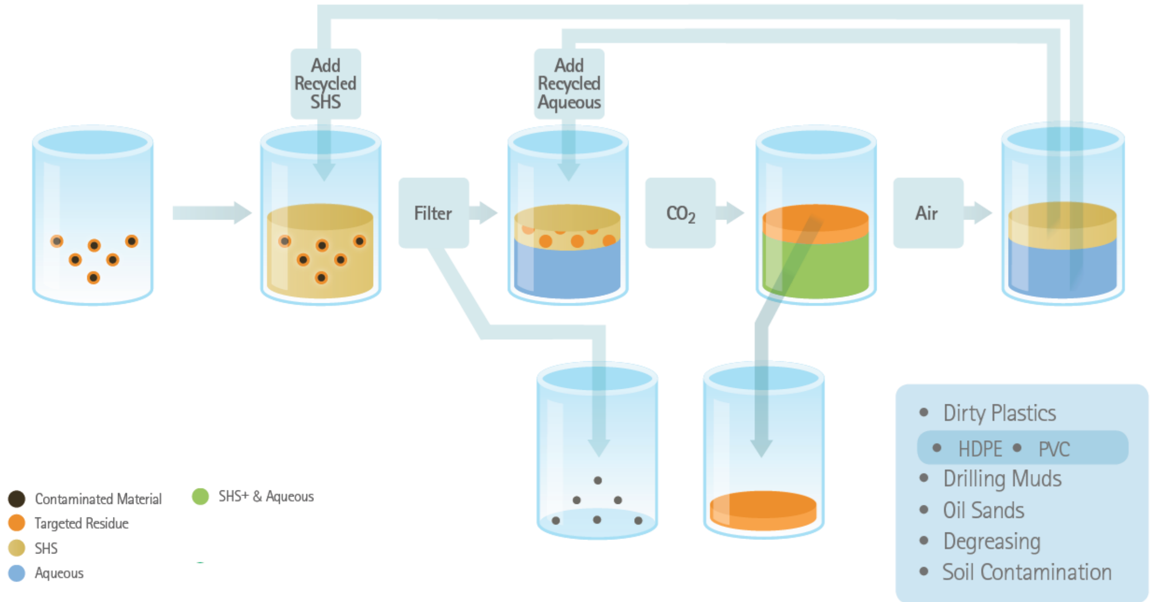


Figure 2. SHS used in cleaning and remediation applications.

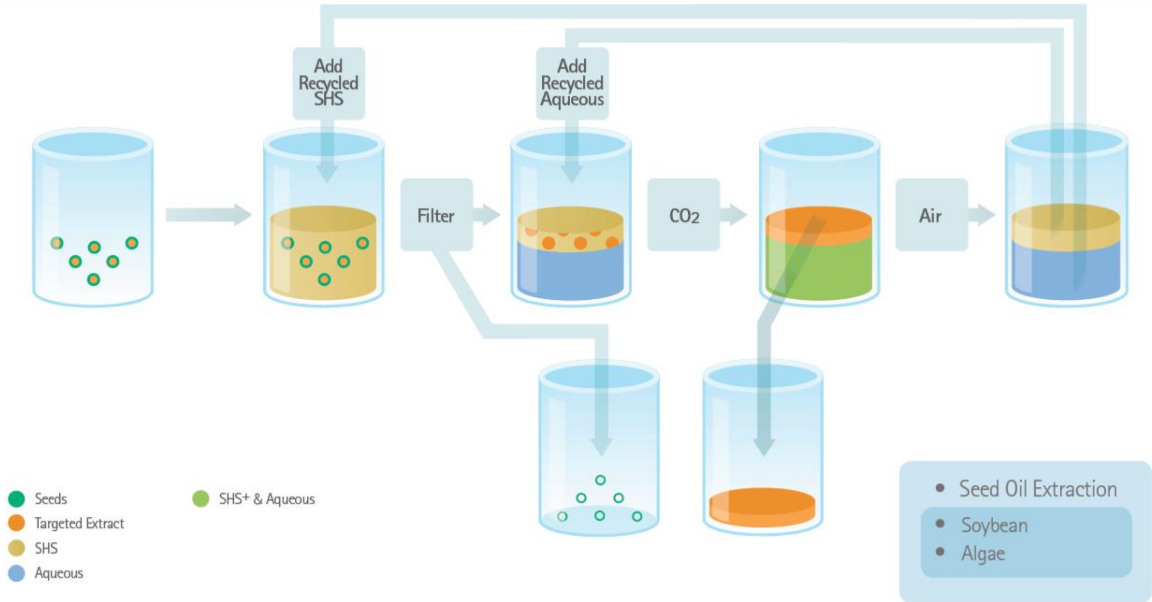


Figure 3. SHS used in extraction applications.

APPENDIX E: CONSULTED DATA SOURCES

Following databases were searched:

- CRC Handbook of Solubility Parameters and Other Cohesion Parameters
- Hansen Solubility Parameters: A User's Handbook
- Hansen solubility parameters (HSPs) are used to predict molecular affinities, solubility, and solubility-related phenomena.
- Alternative Solvents for Green Chemistry: 2nd Edition 2013 (RSC Green Chemistry) by F Kerton, R. Marriott
- Moving towards safer alternatives

  http://www.subsport.eu/
- Reference document on Best Available Techniques on Surface Treatment of Solvents. http://eippcb.jrc.ec.europa.eu/reference/
- European Environment Agency

  http://www.eea.europa.eu/themes/chemicals
- Pollution Prevention for the Metals Finishing Industry - A Manual for Pollution Prevention Technical Assistance Providers

  http://infohouse.p2ric.org/ref/03/02454/prefinop htm
- Solvents Alternative Guide (SAGE) is a comprehensive guide designed to provide pollution prevention information on solvent and process alternatives for parts cleaning and degreasing. SAGE does not recommend any ozone depleting chemicals.

  http://infohouse.p2ric.org/ref/19/18161/index.cfm.htm
- Toxics Use Reduction Institute, Surface Solutions Laboratory, University of Massachusetts Lowe. A database has been created by Surface Solutions Laboratory.

  http://www.cleanersolutions.org/?action=solvent_replace
- Contains health and safety, chemical and physical, regulatory and environmental fate data on a wide range of commercially available solvents.

  http://solvdb.ncms.org/
- Index to Chemical Fact Sheets, which describe the environmental impact and fate of each substance as well as physical properties and uses.

  http://www.speclab.com/compound/chemabc.htm
- The European Solvents Industry Group provides various information about solvents, use, life cycle, environmental impacts and different ways of reducing solvent emissions

  http://www.esig.org/
- Industrial Degreasers & Solvents

http://www.ecolink.com/

- United States Environmental Protection Agency

  http://www.epa.gov/

ANNEX – JUSTIFICATIONS FOR CONFIDENTIALITY CLAIMS[xxxvii]

1 [redacted]

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[xxxvii] This annex will not be made publicly available as part of the broad information on uses package

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