

# ANALYSIS OF ALTERNATIVES

## PUBLIC VERSION

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<b>Substance:</b>	<i>Trichloroethylene</i>
<b>Use title:</b>	<i>Use of trichloroethylene as a solvent in a process to recover and purify resin from process water</i>
<b>Use number:</b>	<i>Use 2</i>

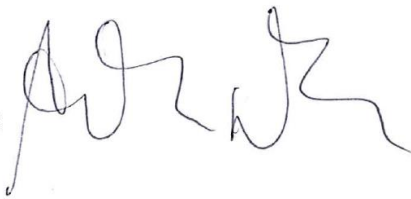
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**IMPORTANT NOTE FOR THE READER**

**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
ATEX	ATmosphères EXplosibles (1999/92/EG & 94/9/EG)
CAS	Chemical Abstracts Service
CBA	Cost Benefit Analysis
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 Disruptor
EEA	European Economic Area
ES	Exposure scenario
EU	European Union
FTE	Full Time Equivalent: measure of headcount
LAD	Latest Application Date
LE	Legal entity
LoA	Letter of Access
LR	Lead Registrant
MDL	Method detection limit
OC	Occupational Condition
OPEX	Operational costs
PPE	Personal Protection Equipment
PERC	Tetrachloroethylene
PPM	Parts Per Million

PSIS	Pre Submission Information Session
PV	Present Value
RAC	Risk Assessment Committee
RCR	Risk Characterization 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 2: the use of TCE (Trichloroethylene EC n° 201-167-4) as a solvent in a closed system for the extraction of synthetic resin from the process water stream. A separate analysis of alternatives has been prepared for Use 1. Some of the process equipment is shared between the two uses, which makes the search for alternatives interlinked and more complex.

The resin used in Vlisco’s dyeing process for 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 2 are considered and five of the most promising are explored in detail. The following types of alternatives were considered:

- Other solvents
- Solvent free extraction

In addition, some of the alternatives explored for Use 1 could potentially serve as effective alternatives for Use 2 by making the need to extract resin from process water redundant.

The results of the analysis show that there is at present no suitable alternative to TCE in Use 2. All alternatives are not yet technically feasible, and (except in one case) could only be adopted 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: Overview of cost for different scenario's to the use of TCE in Use 1 and 2<sup>1</sup>

Option	Use 2			Use 1 and 2
	Risk reduction potential	Implementation period (years)	Present value cost (mio €)	Present value cost Total (mio €)
PERC <b>PERC</b>	Low-zero. similar hazard profile to TCE	4	■	■ 94%
PERC <b>Solvent free extraction</b>	Minimal risks from Use 2 alternative	6	■	■ 100%
Flammable solvent <b>Flammable solvent</b>	Low-zero – additional fire risk	6	■	■ 101%
Flammable solvent <b>Solvent free extraction</b>	Minimal risks from Use 2 alternative	9	■	■ 112%
Rosin <b>Solvent free extraction</b>	Minimal risks from Use 2 alternative	9	■	■ 110%
Switchable solvent <b>Switchable solvent</b>	Minimal risks from use	12+	■	■ 109%
<b>RSP</b>	Minimal risks from use	1		■ 244%

Note

1. Alternatives related to Use 2 are mentioned in **bold**.
2. 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.

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 would effectively make Use 2 redundant. It 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 alternative solvents or solvent free extraction are all estimated to generate significant costs. Where costs appear higher for apparently the same solvent free extraction option, this is because it is expected that implementing this option for Use 2 will take longer than the associated alternative for Use 1 – this difference implies a temporary and costly increase in the consumption of the resist while solvent free extraction is brought on stream.

The least costly alternative available to Vlisco is to switch to an alternative solvent, Perchloroethylene (PERC), for both Use 1 and Use 2, as this solvent has the most similar performance properties to TCE and it is estimated that it could be adopted with the least disruption to Vlisco's production processes and sales markets. The second least costly alternative is to adopt PERC for Use 1 but to combine it with solvent free extraction for Use 2. Due to the aforementioned difference in implementation times, this would imply a significant temporary increase in resin consumption. However, solvent free extraction would not involve the use of chemical solvents for resin recovery. This second combination is the alternative which Vlisco will adopt if it can no longer continue to use TCE past its Sunset Date in mid-2016. Initial planning for this switch has already commenced. Although more costly than a pure PERC solution, Vlisco considers it to be more consistent with its long-term desire to move away from potentially harmful chemical solvents, as well as an appropriate way of managing future regulatory risk associated with PERC.

The cost of the option based on a so-called 'switchable' solvent is estimated to be very significant, reflecting the long implementation period expected as a result of the significant technical uncertainties which would need to be resolved for this option 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 to maintain product quality and also to result in a net reduction in operating costs (due to reduced energy consumption) following transition. The overall net present value cost of the option, if it could be adopted without the need for downtime (e.g. in combination with a positive authorisation decision for instance) could be expected to be relatively low (perhaps towards 5 mio €). These costs (although very uncertain) might fall further if implementation periods could be shortened, to the extent that the investment could potentially 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)<sup>1</sup>, “*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<sup>2</sup> (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<sup>3</sup>

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 Dutch Wax” is as identifiable as the Vlisco brand name (according to WIPO<sup>1</sup>, some customers know these fabrics as Real Dutch Wax whilst others know the products to be produced by Vlisco).

<sup>1</sup> The World Intellectual Property Organisation (WIPO) – “The fabled cloth and its IP future” - <http://www.wipo.int/ipadvantage/en/details.jsp?id=3501>

<sup>2</sup> Waxprints im soziokulturellen Kontext Ghanas, Magisterarbeit, Gabriele Gerlich, 2004

<sup>3</sup> [http://www.vlisco.com/new-arrivals/en/page/538/#/?FK\\_7=42&CPI=0](http://www.vlisco.com/new-arrivals/en/page/538/#/?FK_7=42&CPI=0)

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 phtalogene 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 from 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 and 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 a 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<sup>4</sup>.

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<sup>4</sup> Waxprints im soziokulturellen Kontext Ghanas, Magisterarbeit, Gabriele Gerlich, 2004

### 2.3. Process description

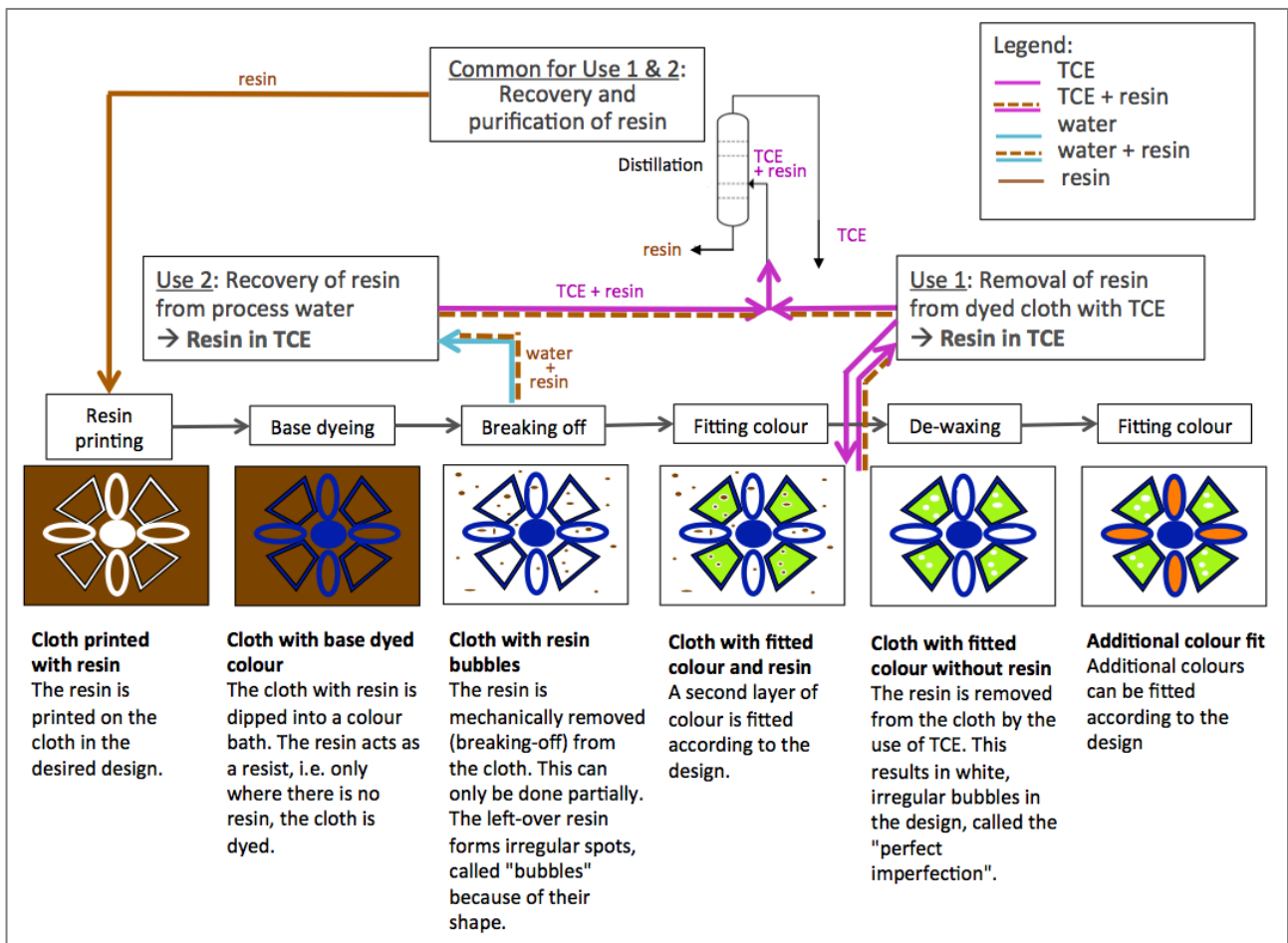


Figure 2: Overview of Use 1 & 2 and the link between the two

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.



The process relevant to Use 2 is separate from, but linked to, the cloth dyeing process. Process water loaded with resin results from the so-called “breaking off” stage (see box 3 in Figure 2) of the process. This means that resin-loaded process water is a direct consequence of the breaking-off stage, which is crucial for the cloth’s characteristic effects such as bubbling and blurred edges. The origin of the resin-loaded process water is intrinsically linked to the specific visual characteristics of Vlisco textiles.

The resin needs to be extracted from the water to allow the discharge of a clean water stream and the recovery of the resin. The resin is extracted from the water using a suitable solvent, currently TCE. TCE dissolves the resin but does not dissolve impurities present in the water and resin phase, which means the recovered resin is free of impurities which would otherwise show up in the printing process when the resin was re-used. Hence, Use 2 of this application for authorisation – the extraction process based on TCE – is at the same time (1) a purification process for the resin, (2) a recovery process for the resin and (3) a cleaning process for the waste water. (Vlisco exploitation permit allows max 500 kg/day and 80 T/year emission of resin to waste water)

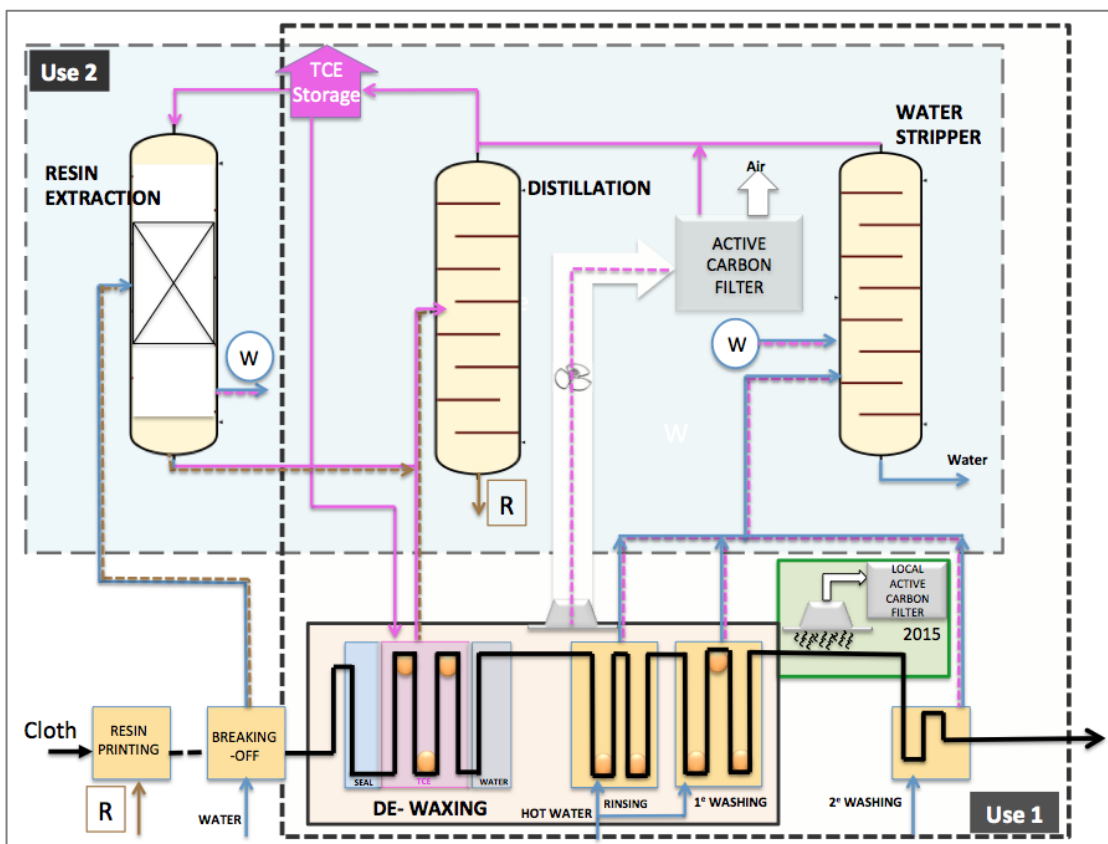


Figure 3: Overview of Vlisco's Use 1 and 2

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 (water from Use 1 and Use 2 which contains TCE 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 re-use 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 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 process of Use 2 consists of 4 distinct steps:

- **Extraction** of resin from water by use of TCE
- **Distillation** Separation and recovery of the TCE and resin (common with Use 1)
- **Air treatment:** Active carbon filter to remove and recover TCE from vapours (common with Use 1)
- **Water treatment:** Removal and recovery of the TCE from the wash water (common with Use 1)

### Extraction (Figure 3, column for resin extraction)

The extraction of the resin from the process water is a closed and continuous process. Water containing suspended resin particles is pumped from the baths where the cloth is washed into an extraction column. The TCE is also pumped into the extraction column but against the flow of the process water. The TCE dissolves the resin particles suspended in the water. The solution of TCE, resin and water is then mixed and allowed to settle. Due to the difference in the densities of the three substances, and the low solubility of TCE in water, the TCE-resin particles separate from the water phase, and the water can be removed from the column with only a low concentration of TCE.

The flow rate through the extraction process is  $\text{m}^2$  per hour of TCE to clean  $\text{m}^3$  per hour of water. The extraction is done at ambient temperature. Contact time for dissolving the resin in the TCE is less than 1 hour. The installation operates at atmospheric pressure.

The extract solution of TCE and resin leaves the column at the bottom and is pumped to the distillation column (common with Use 1) to separate the TCE and the resin. The resin-free water is pumped to the water stripper (common with Use 1) to remove the TCE residues. The pigments and dyes dissolve in the water phase and leave the extraction with the water flow. Indeed, as a valuable side effect of the extraction, the resin is cleaned of dyes and pigments.

### 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 1. 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  $\text{NH}_4\text{OH}$ . 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 1. The average concentration of TCE at the outlet of the active carbon filter is  $6 \text{ mg/m}^3$ , and never exceeds  $20 \text{ mg/m}^3$ ; the maximum concentration allowed in the exploitation permit is  $50 \text{ mg/m}^3$ . 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  $100^\circ\text{C}$  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  $50 \text{ microgram/l}$ . The load of TCE in the waste water is about  $100 \text{ kg/year}$ . The maximum concentration of TCE in the waste-water allowed in the permit is  $300 \text{ microgram/l}$  and the maximum load is  $400 \text{ kg/year}$ .

The recovery rates of resin and TCE need to be as high as possible to reduce costs and environmental impacts. There is no separate mass balance for Use 2 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 steam 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 detect 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	<p><u>Use 2: Use of trichloroethylene as a solvent in a process to recover and purify resin from process water</u></p> <p>TCE is used to dissolve the resin present in the breaking-off process water. The resulting TCE-resin solution is separated from the water phase, and then separated into resin and TCE; both products are reused in the dyeing process (Use 1).</p>
What critical properties and quality criteria must the substance fulfil	<p><u>Hazard properties</u></p> <ul style="list-style-type: none"> <li>• Non flammable</li> <li>• Less hazardous than TCE. Classification of TCE <ul style="list-style-type: none"> <li>○ Skin Irrit. 2 H315</li> <li>○ Eye Irrit. 2 H319</li> <li>○ STOT SE 3 H336</li> <li>○ Muta. 2 H341</li> <li>○ Carc. 1B H350</li> <li>○ Aquatic Chron 3 H412</li> </ul> </li> <li>• Seveso substance: NO</li> </ul> <p><u>Substance Properties</u></p> <ul style="list-style-type: none"> <li>• Solubility of the resin in the substance: resin must be soluble to high loads in the substance to minimize solvent throughput</li> <li>• Solubility speed: the substance must be able to dissolve the resin fast, to minimize the equipment size for a given capacity (Table 5)</li> <li>• Solubility in water: the water solubility of the substance should be low in order to minimize the remaining concentration in wastewater</li> <li>• Flammability: the current installation is not suitable for flammable solvents; therefore, the substance must be non-flammable</li> <li>• Boiling point: defines the design and operational costs of recovery installation. Boiling point should be as low as possible. (Table 5)</li> <li>• Heat of evaporation: defines the energy requirement for the recovery. The heat of evaporation should be as low as possible.</li> <li>• Density: the difference in density between water and the substance defines the size of the extraction/settling equipment. (Table 5)</li> <li>• Stability of the solvent: solvent should be sufficiently stable in contact with water and within the temperature ranges used. Initial decomposition temperature &gt; 120°C. Solvent should have a stable composition during recycling.</li> </ul> <p>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:</p> <p style="background-color: black; color: black;">[REDACTED]</p> <p>In case the substance is replaced by implementation of another technique, the impact of such an alternative on Use 1 and more specifically on the properties of the resist and the final product have to be taken into account.</p> <p>Criteria for acceptability of the final product are summarized in the Appendix C.</p>

Function aspect	Explanation
Function conditions	<ul style="list-style-type: none"> <li>• The installation operates fully continuously 24/24, 7/7.</li> <li>• The extraction is a fully continuous and closed process. The installation is not suitable for flammable products. Throughput rate of the system is ██████████<sup>5</sup> (TCE). More than 99.99% of the TCE used (Use 1&amp;2) is recovered. The resin is recovered at 95% (Use 1&amp;2, overall recovery rate).</li> <li>• Water from the extraction column is steam stripped of TCE before discharge; all vapours are treated by BAT (Best Available Technique) active carbon filters which are regenerated to recover the TCE.</li> <li>• 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 incidents.</li> <li>• A significant part of the TCE consumption is due to decomposition in the process. TCE is used above the temperature for decomposition</li> <li>• In 2013 8T of TCE was consumed in total. Forecast for 2014 and thereafter is 4T/year as result of further process improvement.</li> </ul>
Process and performance constraints	<ul style="list-style-type: none"> <li>• Thermal stability of the resin at conditions (see Section 2.4) 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.</li> <li>• Remaining concentration of solvent in the resin should be sufficiently low to avoid exposure to the solvent in the resin printing process.</li> <li>• Chemical and physical properties of the solvent define the design and operation of the extraction process (see also row 2 in this table: “What critical properties and quality criteria must the substance fulfil”).</li> </ul>
Is this substance associated with another process that could be altered so that the use of the substance is limited or eliminated	<ul style="list-style-type: none"> <li>• The use of the solvent is linked to the use of a resist for the dyeing process (in Use 1) which is soluble in TCE. Alternative processes for Use 1 are described in the AoA for Use 1. In case a suitable alternative could be found for Use 1, which does not make use of a resist, Use 2, which is described in this AoA, would no longer be relevant.</li> <li>• 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.</li> <li>• An alternative resist, which can be used in Use 1 without the use of a solvent, will put specific requirements on Use 2. These are described in this AoA.</li> </ul>
Customer requirements	<p>The internal customer for Use 2 is Vlisco itself (Use 1) where the resin and solvent are applied in the cloth dyeing process. The main requirements for that process are the purity of the resin (&gt;99.8%) and absence of TCE in the resin (&lt; 0.01%). The absence of pigment and cloth particles is particularly important.</p> <p>There is a clear requirement from customers of Vlisco products for the specific Vlisco designs, which are linked to “Real Dutch Wax” and the associated mechanical resist technology (see appendix C). As shown in AoA of Use 1, techniques other than the mechanical resist technique do not yield the same final product.</p>

<b>Function aspect</b>	<b>Explanation</b>
Industry or sector requirements	The exploitation permit allows a daily emission of resin via water of 500 kg and a yearly emission of 80 tonnes. 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 <sup>3</sup> , never exceeding 20 mg/m <sup>3</sup> . The limit in the exploitation permit is 50 mg/m <sup>3</sup> . 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). 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 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 that was collected over the years during various research programs was summarised and completed by systematic study made by an external party in 2013 (Appendix A, document a3).

The focus of the analysis of alternatives (AoA) is on substances or processes, which could form an alternative for the substance function, namely to dissolve and extract the resist from the water phase. A second group of alternatives concerns the combination of a different resist (currently a resin) and a suitable solvent or other removal technique. It is clear that this kind of alternative require more development compared with the first group and has a clear interaction with Use 1.

In the AoA of Use 1, it is also investigated to what extent alternative techniques to imprint the design onto the cloth are suitable from the applicant's perspective. Obviously, in case such an alternative for Use 1 was suitable, this would eliminate the purpose of Use 2 and as such be an alternative. This is reviewed in the AoA of Use 1.

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-Suitability and availability of possible alternatives.

Table 3: List of alternatives

Alternative	Main argument for non-suitability
<b>Different solvent for recovery and purification of resin from water</b>	
a. Solvents with no flash point. (Perchloroethylene)  ALTERNATIVE 2.1	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.  <b>This alternative is elaborated in § 4.1</b>

Alternative	Main argument for non-suitability
b. Solvents with flash point < 55°C (i.e. toluene, ethyl acetate, acetone)  ALTERNATIVE 2.2	Toluene is identified as the flammable solvent with physical properties closest to TCE  (1) Technical feasibility is not proven,  (2) Current installation is not ATEX <sup>5</sup> compliant. Permits for using flammable solvents (>50T) on site not available,  (3) Very high investment costs (ATEX) and higher operational costs, higher compared to alternatives based on non-flammable solvents. Increased OPEX costs.  <b>This alternative is elaborated in § 4.2</b>
c. Solvents with flash point > 55°C (dry cleaning solvents with 10 carbon molecules and higher)	(1) Not technically feasible because no sufficient separation of resin and solvent (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 (resin cost: increase in raw materials cost by 27-30%; ██████████ <sup>6</sup> ).  <b>This alternative is not further analysed in detail.</b>
d. Switchable solvents  ALTERNATIVE 2.5	(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 are expected. Hence, the option has been included in the long-term R&D plan of this AfA.  <b>This alternative is elaborated in § 4.5.</b>
<b>Techniques for Resin Recovery and purification without solvent</b>	
a. Thermal dewatering of the resin sludge & purification by filtration  ALTERNATIVE 2.3	(1) Technical feasibility is not proven.  (2) Very high investments cost to switch to this technology.  <b>This alternative is elaborated in § 4.3</b>
b. Thermal dewatering of the rosin sludge & purification by filtration.  ALTERNATIVE 2.4  Remark: this alternative is relevant if in Use 1 resin would be replaced by rosin.	(1) Technical feasibility is not proven; process for recovering of this resist still needs to be developed. More chemical processing needed due the reactivity of this resist.  (2) Higher discharge of unrecoverable resist to waste water (environmental permit). Therefore increased operational costs due to high losses of resist.  This alternative is linked to the alternative 1.3 developed in §4.3 of AoA of Use 1.  <b>This alternative is covered in § 4.4</b>
<b>No recovery of resin on site</b>	

<sup>5</sup> ATEX: ATmosphères EXplosive: regulation regarding the use of explosive substances (94/9/EG, 1999/92/EG)



Alternative	Main argument for non-suitability
a. Outsourcing resin recovery & purification	<p>(1) Technical feasibility not proven: Similar process development is needed as for in-house solution, which is covered in the other alternatives.</p> <p>(2) Economically not suitable: resin cake (cake: resin + water (20-40%)) must be transported and recovered. After processing, all resin must be transported back to factory. This results in very high operational costs and additional investment costs for the logistics of the resin (&gt;100 tonnes/week) and resin cake.</p> <p><b>This alternative is not further analysed in detail.</b></p>
b. Incineration of used resin	<p>(1) Economically not feasible: Resin consumption would increase by a factor 20 (5% → 100% loss); operational cost for discharge of 100% of the wet resin cake; logistics cost to handle the resin volume; additional investment costs for the loading/unloading installation of the resin and resin cake. 27-30% increase of the raw materials cost.</p> <p><b>This alternative is not further analysed in detail.</b></p>
c. Relocate factory (Use 2) outside EU	<p>Replacing the factory requires very high investment costs; No synergy with the equipment of Use 1. No significant risk reduction, by transition to this alternative, because TCE will still be used. Significant operational cost for the transport of the resin cake to the recovery plant outside the EU and of the recovered resin back.</p> <p><b>This alternative is not further analysed in detail.</b></p>
<b>Production process without resin</b>	
a. Introduce standard textile printing techniques	<p>This alternative is technically not suitable as this yields a different product.</p> <p><b>This alternative is further elaborated in the AoA of Use 1 alternative 1.5.</b></p>

### 3.2. Description of Research & Development efforts

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 and Table 4 gives an overview of the improvements made over time.

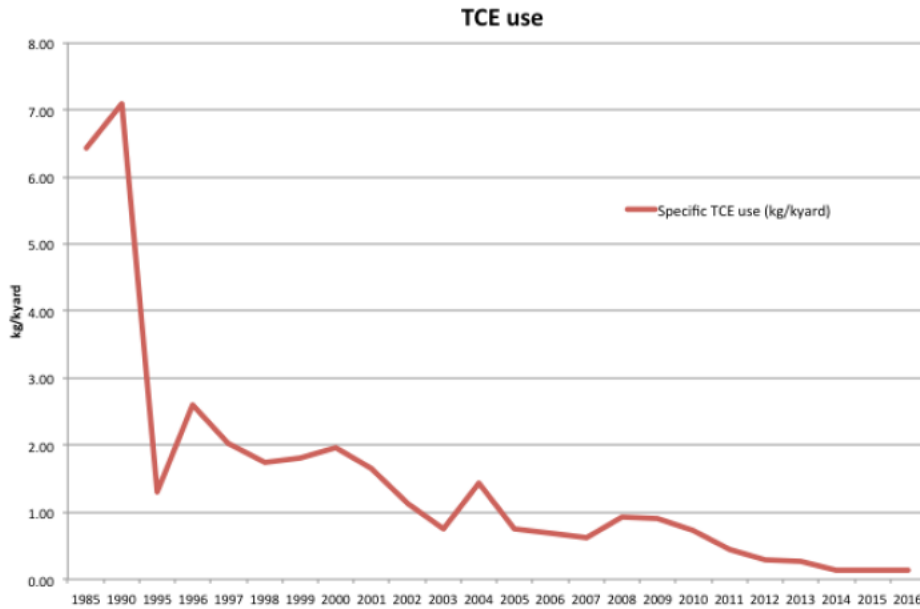
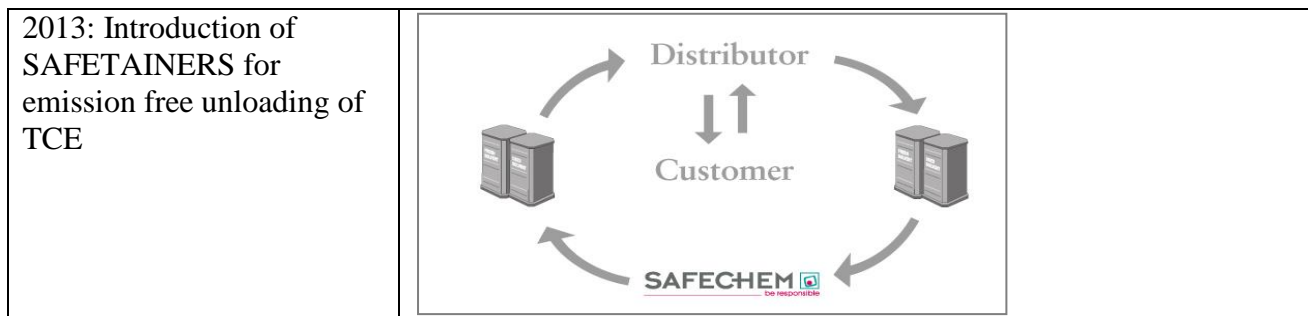


Figure 4: Reported TCE use per yard cloth produced; 2014-2016 are predicted values

Table 4: Process improvements for the reduction of TCE emissions

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

<p>1991: Active carbon filter</p>	
<p>1991: Steam stripping of waste water</p>	
<p>1991-2013</p>	<p>Connecting all water streams to water stripper</p>
<p>2013:</p>	<p>Connecting vents of TCE containing vessels to active carbon filter</p>
<p>2013:</p>	<p>Optimize resin distillation conditions</p>



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 to replace TCE as an extraction solvent needs to account for the interaction of this use with the use of TCE as a solvent to remove resin from the cotton cloth (as described in Use 1 of the application dossier). Both uses are part of an integrated process within Vlisco and use certain equipment in common (e.g. 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 had to be found first for Use 1.

Since 1985 the following two routes for replacement of TCE have been investigated:

1. Drop-in solution: different solvent for the extraction and purification of the resin from water
2. Solvent free recovery and purification of resin from water without solvent

These R&D efforts have led to limited success so far. Several alternatives have been proven not to be suitable, but no suitable alternative has been identified to date.

Ideally the applicant prefers a solvent free option or alternatively a 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)

In respect of a green solvent, the applicant is in the early stages of research with a switchable solvent (see Alternative 5 in Section 4.5). 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 recovery and purification of resin from water
2. Solvent free: recovery and purification of resin without solvent

3. Direct printing
4. Outsourcing
5. Switchable solvents

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

### 1. Different solvent for recovery and purification of resin from water

Over the years, several solvents have been investigated as alternative for TCE to extract the resin from the breaking-off water. These solvents were in the first place evaluated based on the critical aspects relevant for this use (see Table 5):

**Table 5: Selection criteria for non-flammable solvents<sup>7</sup>**

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

These criteria were selected as first screening criteria because of their relevance for the process and because of availability of data. Solvents, which fulfil the criteria above, have to be tested further against other criteria for which specific tests are required. For instance, the solvent needs to be stable in the process conditions to allow a high recovery rate of the solvent and thereby minimize use (and costs). A list of solvents (flammable and non-flammable) that were reviewed is provided in Appendix B. The same criteria as for Use 1 are employed for screening, as the goal is to use the same solvent in both uses (AoA Use 1 Section 3.2). The only non-flammable solvent identified in this research, which could potentially replace TCE in the future (not available before Sunset Date), was PERC. Relevant reports are listed in Appendix A.

### 2. Solvent free recovery and purification

The current extraction process with TCE performs two tasks in one operation:

- (i) Extraction of the resin from the water; and
- (ii) Cleaning of the resin. The contamination of solids present in the resin – such as cotton fibres and dye particles - remains in the water phase, while the resin is dissolved in TCE. The purity of the recovered resin is a critical process parameter in Use 1.

A new technology, not based on a solvent extraction, must as well be able to perform these two tasks in order that the recovered resin can be re-used in Use 1.





### **3. Direct printing**

Direct printing can make Use 2 obsolete for the applicant. See AoA Use 1 (Section 3.2) for details of the research done by the applicant on this topic

### **4. Outsourcing**

This option has been investigated briefly but because of the logistic complexity and the lack of an external partner to work with, further investigations were discontinued.

### **5. Switchable solvents**

Switchable solvents<sup>6</sup> 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<sub>2</sub> the switchable solvent behaves like a traditional, low polarity, organic solvent. On exposure to CO<sub>2</sub> and in the presence of water, the

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<sup>6</sup> [http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-\\$5.48-million.php](http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-$5.48-million.php)

solvent becomes hydrophilic and water miscible. Removal of the CO<sub>2</sub> 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<sup>7</sup>. This breakthrough discovery of CO<sub>2</sub>-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<sup>8</sup> for his CO<sub>2</sub>-triggered control of oil/water mixtures.

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, given the similarity to the current process technology – i.e. solvent extraction of the resin – the chance that the technology can be used for both Use 1 and Use 2 with a similar product image (look & feel), 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<sup>9</sup>. Discussions are ongoing to initiate projects in line with the 12-year development plan as documented in 4.5.2.1.

### 3.2.2. Data searches

All available reports within Vlisco concerning the replacement of TCE have recently been reviewed (2013) by an external engineering company (Appendix A: Overview knowledge documents TCE elimination: document 3a). This review of existing documents was combined with the internal engineering knowledge of this engineering company and consultations with external specialists. The results of this review have been included in the detailed analysis of alternatives as described in section 4.

See also Appendix E: Consulted data sources

### 3.2.3. Consultations

Resin recovery is a very specific and complex subject and as far as we know this is not done elsewhere. The technology is developed specifically for this purpose at Vlisco with support from engineering firms and many years of investigations on pilot scale. No standard processes or technology is available for this specific process.

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<sup>7</sup> <http://www.chem.queensu.ca/people/faculty/jessop/switchable.html>

<sup>8</sup> [http://www.eni.com/eni-award/eng/vincitore\\_2013\\_philip\\_jessop.shtml](http://www.eni.com/eni-award/eng/vincitore_2013_philip_jessop.shtml)

<sup>9</sup> <http://www.switchablesolutions.com/>

Recently, in the context of the data search mentioned above, Prof. Picken (TU Delft) was consulted on possible alternative processes for this use of TCE. The results of these consultations have been included in the list of alternatives in this report.

At various points in time, equipment suppliers were consulted for the supply of equipment suitable for the recovery of resin from the breaking-off water (see also Use 1).

On the topic of switchable solvents, the applicant has been in contact with GreenCentre Canada and Switchable Solutions Inc..



#### 4. SUITABILITY AND AVAILABILITY OF POSSIBLE ALTERNATIVE

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

ALTERNATIVE 2.1: Different non-flammable solvent for recovery of the resin from the water; (Perchloroethylene)

ALTERNATIVE 2.2: Different flammable solvent for recovery of the resin from the water; (Toluene)

ALTERNATIVE 2.3: Solvent free extraction of resin from the water

ALTERNATIVE 2.4: Different resist, i.e. rosin or modified rosin in combination with solvent free extraction of the resist from the water

ALTERNATIVE 2.5: Switchable solvent

In this section, each alternative is evaluated in terms of its *(i)* technical feasibility, *(ii)* economic feasibility, *(iii)* potential for risk reduction, and *(iv)* 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 1, 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 resin recovery installation is well maintained, 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 continuous extraction technology to recover resin from the water stream dates from 1983 when the complete installation was renewed. This was a significant improvement compared to the previous batch technology. The extraction process has further evolved with the current high recovery rate as result. Additions have also been made to improve the TCE use and reduce exposure over the period 1983-2014 (see Table 4). There are no intentions to replace the equipment, nor is any major overhaul foreseen.

#### 4.1. ALTERNATIVE 2.1: different non-flammable solvent (PERC)

Current solvent TCE is not flammable. This Alternative 2.1 considers other non-flammable solvents which can fulfil the function of TCE. From the investigated solvents, mentioned in the list attached (Appendix B), perchloroethylene (PERC) has been identified as a potential alternative for Use 1 and 2. In this case, PERC would be a direct replacement for TCE as a solvent for the resin.

##### 4.1.1. Substance ID and properties

Several solvents are evaluated for extracting the resin from the water. These are mentioned in APPENDIX B: alternative solvents. For each of the solvents the five relevant properties are mentioned:

Table 6 Relevant properties of solvents which can be used to extract resin from water<sup>9</sup>

Property	Criteria
Speed of solubility for resin	████████████████████ compared to TCE
Solubility in water of solvent	████████████████████
Flammability	none
Boiling point	████████████████████
Density compared to water	████████████████████

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 (Appendix A, document 3a).

Table 7 Properties for 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 <sub>2</sub> Cl <sub>4</sub>
Molar mass	165.83 g mol <sup>-1</sup>
Density	1.622 g/cm <sup>3</sup>
Melting point	-19 °C
Boiling point	121.1 °C
Solubility in water	0.015 g/100 mL (20 °C)
Hazards	
Harmonized:	
Carc. 2	H351
Aquatic Chronic 2	H411
Self classification:	
Skin Irrit 2	H315
Skin Sens 1B	H317
STOT Single Exp 3	H336
Other	
Seveso	YES 9ii (R51)

IUPAC name: Tetrachloroethene	
Other names: Perchloroethene; Perchloroethylene; PERC; PCE	
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 6. 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 assessment, 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.

In theory it should be technically possible to use perchloroethylene (PERC) in the extraction process. However, there are a number of physical differences with TCE that lead to difficulties that cannot be disregarded:

- Dissolving the resin (resin extraction):** The speed of dissolving resin in PERC is  $10^2$  lower than in TCE. Hence, the required residence time for the extraction process increases. To cope with this higher residence time, either the throughput has to be reduced or the equipment needs to be replaced with larger equipment. Reduction of the extraction capacity is not acceptable as this would lead to a reduced overall capacity of the site. The necessary adaptation of the current extraction process is unknown although it is likely that a second extraction line has to be built.
- Contact time in the extractor (resin extraction):** Due to the larger density difference between the solvent and water, the water will separate faster from the organic PERC phase than in case of TCE. Hence, the hold-up in the gravity-based extraction process will be shorter. This will lead to a reduced contact time between the two phases. In combination with the slower dissolving (see above), will require further modification of the equipment. In summary, the slower dissolving rate and the higher density difference between PERC and water together result in a significantly reduced dissolving capacity in comparison with the current installation with TCE.
- Resin-Solvent separation (see also Use 1):** Separation of the resin from the solvent will be more difficult due to the ca. 30°C higher boiling point of PERC (PERC  $T_{\text{boil}} = 121^\circ\text{C}$ ; TCE  $T_{\text{boil}} = 87^\circ\text{C}$ ). Increased concentration of solvent in the resin cannot be accepted for  $10^2$

<sup>11</sup>, more importantly, to avoid exposure of workers 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 distillation to separate the resin from the solvent. This will lead to additional thermal degradation of the resin resulting in a change of viscosity and glass transition temperature of the resin. Therefore, longer stripping times and higher temperatures 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 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 the PERC in the resin would be a factor 9 higher than with the TCE.

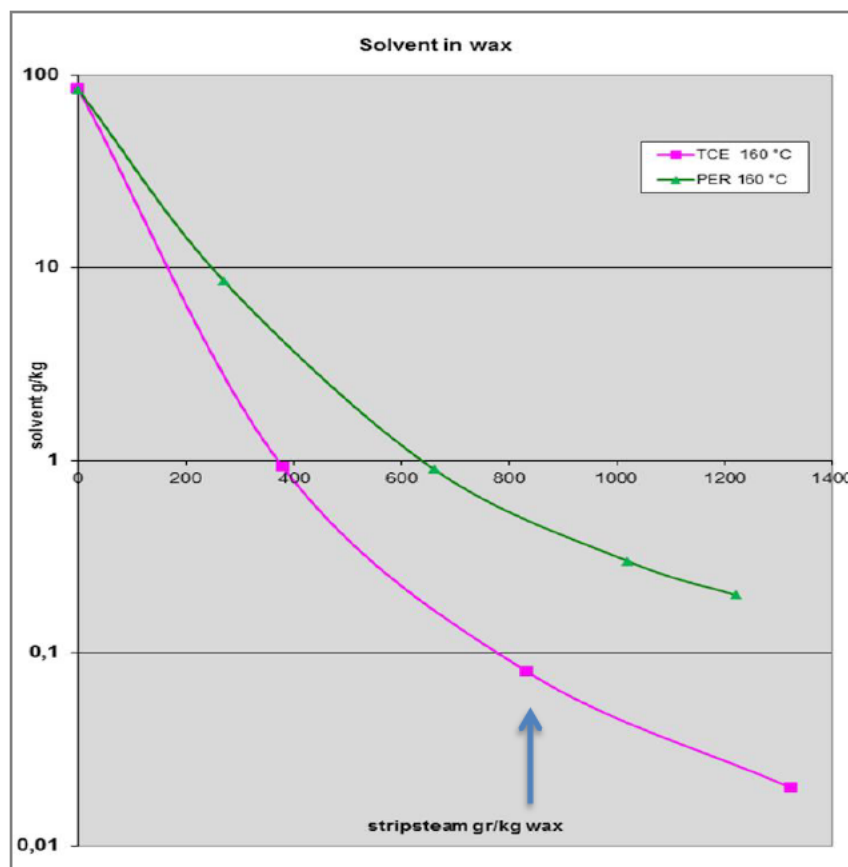


Figure 5: Steam stripping of PERC versus TCE

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 (dyeing, colour printing, drying, washing) 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 PERC of 4,400 kg is created in the factory.
- An increased PERC concentration in the resin also leads to an additional PERC emission to wastewater. Although Vlisco undertakes waste water 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 is extra in the waste water 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 1):** 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 steam-stripping installation. An alternative process will have to be developed and built to achieve a sufficiently low – in respect of the limits imposed by a new permit - concentration of solvent in the waste-water.

The estimated time needed to develop a PERC-based alternative for Use 2 is four years,.

#### Conclusion:

The technical feasibility of the replacement of TCE by PERC for Use 1 is not proven. Hence, PERC cannot be considered a suitable drop-in substance until all design issues have been resolved. Although a switch from TCE to PERC is technically feasible from a theoretical point of view, more development needs to be done on the process conditions and process re-design and process modifications will be needed. Four years is estimated for full implementation of this alternative.

#### **4.1.3. Economic feasibility**

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

- Capital cost
- Increased 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 recovery with PERC will not be available until one year after start-up of PERC Use 1
- 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. the following main investments are required:

- Modification of current extraction tower for resin recovery
- Replacement of water stripper with different technology

All other modifications needed for the shared equipment are covered by the investments costs mentioned in Alternative 1.1 of AoA of Use 1.

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). Details are provided in Table 8 below:

Table 8: Breakdown of investment costs ALTERNATIVE 2.1<sup>12</sup>

Type of cost	Description	Cost estimate (€million)
Equipment	Modification of extraction equipment. New water stripper	■
Installation	Installation factor 0,6	■
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 <sup>10</sup> .	■
Engineering and Project management support	Estimated Engineering and project management is 20% of equipment and installation cost	■
<b>Total</b>		■ PV ■

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 to extract the resin out of the water with PERC. Such an installation still needs to be designed and installed. It was estimated this would take about 4 years.

<sup>10</sup> 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](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf)

The estimated investment cost for this alternative has been estimated to ██████████ €<sup>13</sup> (PV ██████████) <sup>14</sup> for the part specific to Use 2. The modifications required to the process, which is shared with Use 1, are included in the investment cost of Use 1.

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

No change in operational cost is expected.

#### 4.1.3.3 Downtime Costs

Depending on the choice of the alternative for Use 1, there can be a period of time when Use 1 (de-waxing) is in operation while the resin recovery from the breaking-off water is not yet commissioned. During that period of time, the resin from the breaking-off process will have to be disposed of and replaced with new product. This creates an increase in the raw materials cost of 27-30%. Waste handling is an additional cost in this scenario.

This alternative in combination with PERC as solvent for Use 1 creates an additional cost of ██████████ <sup>15</sup> during first year of operation. The PV for this over the period 2016-2034 is ██████████ <sup>16</sup>

#### 4.1.3.4 Conclusion on economic feasibility of Alternative 2.1

Table 9 summarises the preceding discussion and presents the estimated costs of implementing the PERC alternative for Use 2. The total present value cost over the period 2016-2034 is estimated to be around ██████████ <sup>17</sup> (discounted at 10%). The largest proportion of this cost is the estimated additional cost of raw materials during the implementation period. The alternative to switch to PERC for Use 2 is economically not feasible. There are also negative qualitative impacts, such as the risk associated with the possible future regulation of PERC (see 4.1.4. ).

The conclusion is that the alternative to switch to PERC for Use 2 is currently not economically feasible.

Table 9: Overview costs for Alternative 2.1<sup>18</sup>

Different non-flammable solvent for dissolving current resin from the cloth: Perchloroethylene		
Implementation time	4 years	- Design PERC based resin recovery - modification of resin recovery - Alternative water stripping technology
Investment cost (PV)	██████████	- New equipment and installation of equipment
Impact on OPEX (PV)	█	- no impact
Transition cost (PV)	██████████	- No wax recovery during first year of operation
Total (PV)	██████████	

Note

1. The investments considered in this scenario are:

- Modification of current extraction tower for resin recovery
- Replacement of water stripper with different technology

All other modifications needed for the shared equipment are covered by the investments costs mentioned in Alternative 1.1 of AoA of Use 1.

#### **4.1.4. Risk reduction potential**

Of the solvents listed in appendix B, only 1,1,1-Trichloroethane and PERC fulfill the criteria mentioned in Table 5. 1,1,1-Trichloroethane was disregarded on the basis of its ozone depleting properties (Montreal Protocol, Annex B of controlled substances<sup>11</sup>). 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.

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<sup>11</sup> [http://ozone.unep.org/new\\_site/en/Treaties/treaties\\_decisions-hb.php?art\\_id=59,60,61,62,63](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 10

**Table 10: Hazard properties of PERC and TCE**

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

\* relates to endpoints with a harmonized classification

\*\* Annals of Neurology, Volume 71, Issue 6, pages 776–784, June 2012

\*\*\* PERC as EDC, Cat 2 according to EU COM dbase<sup>12</sup>

<sup>12</sup> [http://ec.europa.eu/environment/chemicals/endocrine/strategy/substances\\_en.htm#priority\\_list](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 CERINITE Hazard Assessment No.65 (2005), ATSDR (1997)<sup>13</sup> and NICNAS (2001)<sup>14</sup> 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)<sup>15</sup>.

#### Europe:

- Perchloroethylene is listed on the EU database for endocrine disrupting compounds<sup>16</sup> 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)<sup>17</sup>.

<sup>13</sup> ATSDR (1997). Toxicological profile for tetrachloroethylene (Update). U.S. Department of Health and Human Services, Agency for Toxic substances and Disease Registry.

<sup>14</sup> NICNAS (2001). Tetrachlorethylene – Priority Existing Chemical assessment report No. 15

<sup>15</sup> 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.

<sup>16</sup> EU ED database: [http://ec.europa.eu/environment/endocrine/strategy/short\\_en.htm](http://ec.europa.eu/environment/endocrine/strategy/short_en.htm)

<sup>17</sup> 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)<sup>18</sup>

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, Lindholm, et al, 1992, Kyronen 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<sup>19</sup> 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<sup>20</sup> 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:

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<sup>18</sup> <http://www.subsport.eu/?s=perchloroethylene> and <http://www.subsport.eu/wp-content/uploads/data/perchloroethylene.pdf>

<sup>19</sup> [http://echa.europa.eu/documents/10162/19126370/svhc\\_roadmap\\_implementation\\_plan\\_en.pdf](http://echa.europa.eu/documents/10162/19126370/svhc_roadmap_implementation_plan_en.pdf)

<sup>20</sup> 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)<sup>21</sup>, SCOEL 2009 (PER)<sup>22</sup>), 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.”*

### **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:

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<sup>21</sup> EU (2004). European Union Risk Assessment Report: Trichloroethylene. 1st Priority List, Volume 31. European Chemicals Bureau, European Commission, EUR 21057 EN, 2004.

<sup>22</sup> SCOEL (2009). Recommendation of the Scientific Committee on Occupational Exposure Limits for Tetrachloroethylene (Perchloroethylene). SCOEL/SUM/133 June 2009.

*“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<sup>23</sup>.

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.

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

<sup>23</sup> 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

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

#### **Emissions via resin**

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.

#### **Emissions to waste water**

- 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 steam 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.

<b>Conclusion on the reduction of risk due to transition from TCE to PERC</b>
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**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).**

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<sup>24</sup> (cfr. Cat 1B)
  - Vlisco cannot judge the classification of PERC, however Vlisco is sincerely concerned about replacing one carcinogen with 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.
- (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<sup>25</sup> of the European Commission as EDC Cat 2,
  - b. PERC is listed on CoRAP<sup>26</sup>, 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)<sup>27</sup>.

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<sup>28</sup>: 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

<sup>24</sup> <http://www.epa.gov/ttn/atw/hlthef/tet-ethy.html>

<sup>25</sup> EDC database EUCOM: [http://ec.europa.eu/environment/chemicals/endocrine/strategy/substances\\_en.htm](http://ec.europa.eu/environment/chemicals/endocrine/strategy/substances_en.htm)

<sup>26</sup> CoRAP: <http://echa.europa.eu/documents/10162/49a3c3f1-3afe-4816-a62b-82a8d64496fc>

<sup>27</sup> Source: Regulation No 1272/2008 Annex VI (GHS/CLP)

<sup>28</sup> SVHC Roadmap 2020 (9 Dec, 2013):

[http://echa.europa.eu/documents/10162/19126370/svhc\\_roadmap\\_implementation\\_plan\\_en.pdf](http://echa.europa.eu/documents/10162/19126370/svhc_roadmap_implementation_plan_en.pdf)

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.

#### **4.1.5. Availability**

PERC is available on the market in sufficient quantity. The design of the modifications to the resin-solvent and solvent-water separation has not been done yet.

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 be needed. Given that PERC is listed as a SEVESO substance, it is not certain whether the permit will be granted. 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 not known at present, 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 installation has an estimated time-line of four years. This means that the alternative will not be available by the Sunset Date.

#### Conclusion:

The alternative use of PERC instead of TCE is currently not available to the applicant and will not be by the Sunset Date. Several elements such as the exploitation permit and the required equipment are not available now and will require several years of technical development and implementation.

#### **4.1.6. Conclusion on suitability and availability for Alternative 2.1**

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

Technically it is not feasible to be used instead of TCE today, as significant process development is still needed.



Economically it is not feasible, as it requires high-risks investments and will result in significant (albeit temporary) increases in raw material consumption. Finally, the lack of an exploitation permit for the use of PERC and the associated uncertainty, and the long lead-time for technical development and implementation, mean that PERC as an alternative cannot be considered available. It is estimated that technological development and investment to implement the PERC alternative would take approximately 4 years. In the meantime, Vlisco would have to increase its consumption of resin to offset the reductions in resin recovery, thereby also increasing costs.

## 4.2. ALTERNATIVE 2.2: flammable solvent

The current solvent TCE is not flammable. Alternative 2.2 considers flammable solvents which can fulfil the function of TCE. Of the investigated solvents mentioned in the list attached (Appendix C), Toluene has been identified as an alternative for investigation both for Use 1 and 2. In this case, Toluene would be a direct functional replacement for TCE as a solvent for the resin.

### 4.2.1. Substance ID and properties

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

Table 11 Relevant properties of flammable solvents which can be used to extract resin from<sup>19</sup>

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

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

Table 12 Properties of Toluene

IUPAC name: Methylbenzene	
Other names: Toluene	
Identifiers	
CAS number	108-88-3
EC number	203-625-9
Properties	
Molecular formula	C <sub>7</sub> H <sub>8</sub>
Molar mass	92.14 g mol <sup>-1</sup>
Density	0.87 g/cm <sup>3</sup>
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
Other	
Seveso	YES 7b
REACH status	

IUPAC name: Methylbenzene
Other names: Toluene
Substance is registered

#### 4.2.2. Technical feasibility

##### Toluene as a flammable solvent

The current process installations at Vlisco have been designed for a non-flammable solvent. The installation does not comply with the ATEX<sup>29</sup> 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. But also equipment located near the location where Toluene is used, can be subject to ATEX.

In the AoA of Use 1 Section 4.2.2 the option described is to move the de-waxing and related equipment – distillation and water stripping - to another location to avoid a major upgrade of equipment in the vicinity of a flammable solvent (See Figure 6 in Section 4.2.2 of AoA, Use 1).

In this case Use 2 would be entirely relocation, i.e. resin extraction, distillation, water stripper and active carbon filter the latter is connected the central vent system of the equipment (see Figure 6, central vent system not on the drawing). In this case the bulk of the water needs to be separated from the resin by filtration. As shown in Figure 6 the resulting wet resin cake needs to be transported to another location and resin returned to the Helmond site. This option results in the installation of an additional resin-solvent distillation and water stripper off-site.

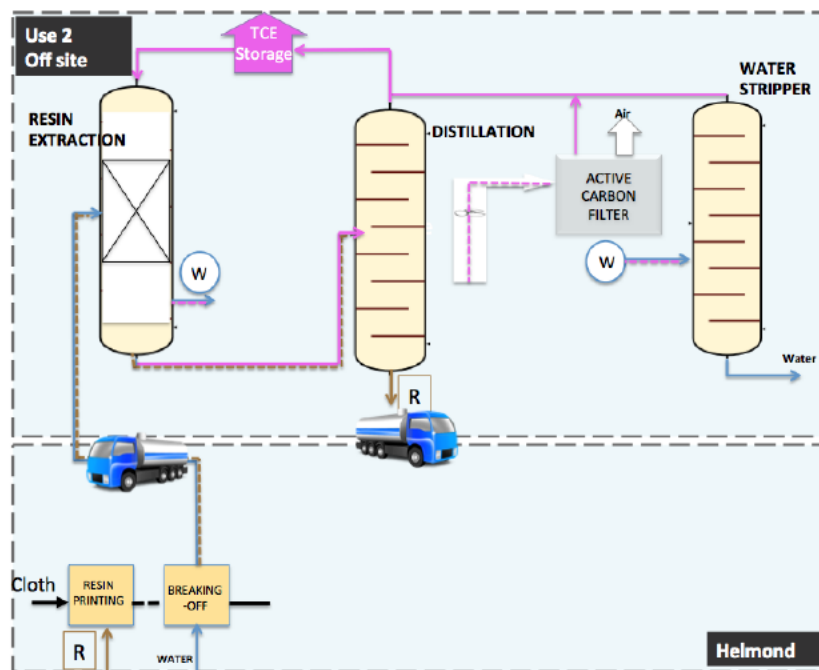


Figure 6: Flammable solvent for recovery of resin off site

<sup>29</sup> ATEX: ATmosphères EXplosive: regulation regarding the use of explosive substances (94/9/EG, 1999/92/EG)

**Use of a solvent with different properties**

All flammable solvents listed in Appendix B, meeting the criteria of Table 11, have a lower solubility speed of the resin. The extraction equipment has to be re-engineered for this different speed of solution. The re-design of the equipment must also account for differences in the densities of the solvents relative to water. Similar problems are expected to arise with Toluene as explained for PERC. (see section 4.1.2. ):

- Dissolving of the resin
- Contact time
- Resin-solvent separation in relation to the boiling temperature of solvent
- Solvent-water separation

Each of these process steps are defined by the properties of the solvent used. Technical adaptations 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, a different technology will have to be developed, as the current water stripping will no longer be suitable. Also 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.

It needs to be emphasized that replacement of TCE by another solvent in Use 2 goes hand-in-hand with the suitability of the same solvent for Use 1. Indeed, if any of the flammable solvents would be suitable for Use 2 and for Use 1, then also the equipment in Use 1 shall be replaced by ATEX compliant equipment. To avoid this additional cost, another solvent or a solvent-free alternative could be considered for Use 1. On the other hand, in case for Use 1 a different solvent is chosen, an additional resin recovery section, water stripping and air treatment (active carbon) will have to be installed to handle the two different solvents. Hence, in both cases significant investments will be required.

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 a solvent has not been proven. The hazard profile of toluene is also not favorable.

The development time for the process is estimated at six years. This is a longer period compared to the development of a process for non-flammable solvent because of the complexity associated with the flammability and the implementation of the ATEX regulations. The applicant is not familiar with the technology to handle flammable liquids.

**Conclusion:**

The technical suitability of none of these flammable solvents, including Toluene, has 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. The development time is estimated at six years for a Toluene based alternative.

#### 4.2.3. Economic feasibility

The alternative to use a flammable solvent can, in principle, be implemented on the current site or on a new site. In this feasibility study only the on-site scenario is evaluated, due to the technical difficulties related to transport of resin containing high loads of water.

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

- Capital cost
- Increased 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
- The resin recovery with Toluene will be available at the same time as Toluene Use 1
- 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 required:

- Replacement of current extraction tower for resin recovery
- Modifications to existing equipment (or replacement) to comply with ATEX

All other modifications needed for the shared equipment are covered by the investments costs mentioned in Alternative 1.2 of AoA of Use 1.

The investments 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 13 below:

Table 13: Breakdown of investment costs of Alternative 2.2<sup>20</sup>

Type of cost	Description	Cost estimate (€million)
Equipment	New extraction equipment. Modifications to existing equipment	■

Type of cost	Description	Cost estimate (€million)
Installation	Installation factor 0,6	■
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 <sup>30</sup> .	■
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	■
<b>Total</b>	<b>PV</b>	■ ■

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 to handle Toluene. Such an installation still needs to be designed and installed. It was estimated this would take about six years. The majority of the work is associated with the adaptation of the installation to comply with the ATEX regulations. The estimated investment cost for this alternative has been estimated to ■ €<sup>21</sup> (PV ■) <sup>22</sup> for the part specific to Use 2.

#### 4.2.3.2 Operational cost

No change in operational cost is expected.

#### 4.2.3.3 Downtime costs

No downtime costs would accrue with this option, because the implementation period is estimated to be the same as that for the associated option for Use 1. Therefore, the two options would be operational at the same time. Downtime costs would accrue as a result of the Use 1 alternative, and are considered in the AoA for that use.

#### 4.2.3.4 Conclusion on economic feasibility of Alternative 2.2

Table 14 summarises the preceding discussion and presents the estimated costs of implementing the Toluene alternative for Use 2. The total present value cost over the period 2016-2034 is estimated to be around ■<sup>23</sup> (discounted at 10%). This is accounted for entirely by capital expenditure,

<sup>30</sup> 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](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf)

with no expected impact on operating costs or downtime. The alternative to switch to Toluene for Use 2 is economically not feasible. There are also negative qualitative impacts, such as the fire risk associated with the use of Toluene (see Section 4.2.4. ).

Table 14: Overview costs for Alternative 2.2<sup>24</sup>

Different flammable solvent for recover current resin from the water: Toluene		
Implementation time	6 years	- New Toluene based extraction equipment - Modification of resin-solvent separation - Alternative water stripping technology
Investment cost (PV)	████████	- New equipment and installation of equipment
Impact on OPEX (PV)	█	- no impact
Transition cost (PV)	█	- none, assuming the implementation takes not longer than to implement the Use 1 alternative
Total (PV)	████████	

Note

1. The investments considered in this scenario are:

- Replacement of current extraction tower for resin recovery
- Modifications to existing equipment (or replacement) to comply with ATEX

All other modifications needed for the shared equipment are covered by the investments costs mentioned in Alternative 1.2 of AoA of Use 1.

#### 4.2.4. Risk reduction potential

The overall reduction of risk has not been investigated in detail as the technical feasibility of flammable alternatives has not been proven. Moreover, economic feasibility is less favourable compared with the non-flammable solvent so priority has been given to this range of solvents for further investigation.

Similar to PERC, Toluene is a solvent with a higher boiling point compared with TCE. As demonstrated in section 4.1.2. , solvents with higher boiling point may lead to higher solvent concentrations in the resin. Some of the resin is lost to the waste water. Via that route an additional emission of solvent can occur in case of use of high boiling solvents.

It is however clear that the use of a flammable solvent introduces a significant new risk to 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 of the Member State responsible, it was not proposed to bring the substance forward for authorisation or restriction.

#### Conclusion:

There are flammable solvents available with a more favourable hazard profile for human health or environment compared with TCE. In the current installation, it is estimated that the emissions of Toluene would be higher compared with the TCE emissions. The use of

flammable solvents introduces a new and significant explosion 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.

As discussed in Section 4.2.2, the modifications of existing equipment or new equipment will not be available by the Sunset Date for TCE.

The introduction of flammable solvents will require either an update of the current exploitation permit for the current location or, 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 a off-site installation, a seven year implementation time is estimated. In this feasibility study only the on-site scenario is evaluated, due to the technical difficulties related to transport of resin containing high loads of water.

#### **Conclusion:**

Although the substance is available to the applicant, 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.

Hence, the technology will not be in place by the Sunset Date and as such the technology is not available for implementation.

#### **4.2.6. Conclusion on suitability and availability for Alternative 2.2**

A number of flammable solvents have been investigated. Based on a first screening, Toluene was identified as a potential alternative for Use 1 for both Use 1 and 2. However, Toluene for Use 2 (and Use 1) is currently not considered a suitable or available alternative.

The technical feasibility has not yet been proven. In addition, flammable solvents introduce a severe new risk. Significant technical modifications are required to handle this risk. The development time is estimated to be six years. Implementation costs can only be estimated with significant uncertainty, but it is clear that the economical feasibility will be less favourable compared with a non-flammable solvent, due to the adaptations needed to meet the ATEX regulations. It is very uncertain that an exploitation permit will be granted for the use of flammable solvents at the current location.



### 4.3. ALTERNATIVE 2.3: Solvent free extraction in combination with resin

With this alternative, the scope of the investigation is widened to other techniques to replace the function of the substance. The impact on the process of such alternatives is significantly larger compared with a drop-in solution where the direct function of the substance is replaced.

As will be shown, a solvent free extraction as an alternative to Use 2 has to be developed in combination with the decision for an alternative for Use 1. This section 4.3 describes the case where the current resist is still used. In the next section (Alternative 2.4, Section 4.4), the case with another resist than resin, is described.

#### 4.3.1. Description of the technique

This technique differs from the other techniques in respect that no solvent is used to separate the resin from the water. This technology is based on a combination of mechanical and thermal separation. This technology has been identified as an alternative on a conceptual basis and a limited number of trials. However, so far insufficiently detailed experiments or tests have been done to validate the practicality of this technology (see R&D part section 3.2).

The current extraction technology by its nature allows separating the resin from the water, but also has a positive side effect that impurities in the resin are washed out from the resin phase and remain in the water phase. This side effect has proven to be paramount for the quality of the dyeing process and for the high recovery rate achieved of the resin. Any alternative technology will also have to provide a solution to this challenge. Tests have shown that, especially for small particles, this is difficult.

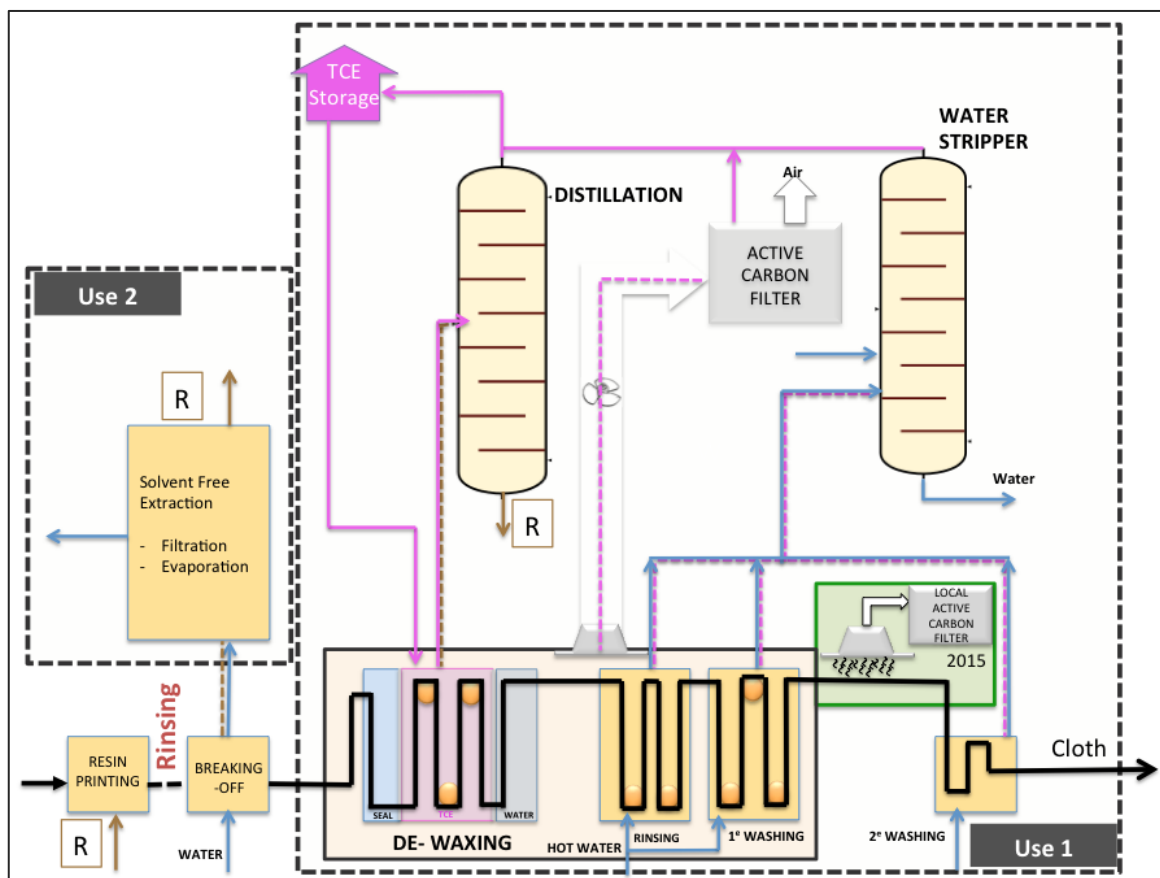


Figure 7: Solvent free extraction of resin from water

Important to notice that in case a resin is used as resist, there is no integration or overlap with the installation for Use 1. This technology consists of following steps (see Figure 7):

- **Rinsing step:** [REDACTED]

- **Filtration:** [REDACTED]

- **Thermal evaporation:** [REDACTED]

- [REDACTED]

#### 4.3.2. Technical feasibility

Conceptually the process described above could provide an alternative. In practice, the following issues still need to be resolved:

- [REDACTED]



The development of this technology needs to be done in combination with the development of the technology for Use 1. Depending on the choices made in Use 1, this alternative may be more or less feasible. Depending on whether a feasible alternative solvent can be found for Use 1 or an alternative resist can be developed which allows the use of safer solvents, the design for this alternative will be challenging.

A long term development and implementation plan has been established to estimate the time needed to develop a solvent free alternative for Use 2. This plan on its own will take about 6 to 9 years depending on the choice of alternative in Use 1. The implementation plan will have to be integrated with the development and implementation plan for Use 1.

#### Conclusion:

The technical suitability of the solvent free extraction process has not been proven. Several process steps still need to be developed and the equipment still needs to be designed. However, it is an alternative that has the potential to be part of a solvent-free solution, as well as being compatible with the use of alternative solvents such as PERC.

#### **4.3.3. Economic feasibility**

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

- Capital cost
- Increased operational cost
- Costs associated with downtime

Costs associated with the remaining book value of the equipment, which is replaced, is not taken into account. This alternative can be combined with a flammable (Toluene) or non-flammable solvent (PERC) for the removal of the resin from the cloth in Use 1. This choice will have an impact on the project time-line, investment cost, and transitional costs, but no effect on operational costs. The additional costs for external de-waxing with Toluene are covered in Use 1.

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
- In combination with PERC, solvent free extraction will not be operational before end 2021
- In combination with Toluene, solvent free extraction will not be operational before July 2024
- 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 required:

- Installation for solvent free extraction

In case this alternative is combined with external de-waxing with Toluene, the overall investment cost is estimated to be slightly higher because no synergy will be possible with Use 1.

The investments 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 15 below:

**Table 15: Breakdown of investment costs for Alternative 2.3<sup>27</sup>**

Type of cost	Description	Cost estimate (€million)	
		PERC (Use 1)	Toluene (Use 1)
Equipment	New installation for solvent free extraction	■	■
Installation	Installation factor 0,6	■	■
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 <sup>31</sup> .	■	■
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	■	■
<b>Total</b>		■	■

<sup>31</sup> 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](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf)

Type of cost	Description	Cost estimate (€million)	
	PV	■	■

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 solvent free extraction. Such an installation still needs to be designed and installed. It was estimated this would about 6 or 9 years in combination with PERC or Toluene respectively.

The modifications required to the process, which is shared with Use 1, is included in the investment cost of Use 1.

#### 4.3.3.2 Operational cost

As shown in section 4.3.2. solvent free extraction will lead to an additional ■<sup>28</sup> loss of resin. Hence, it is expected that the loss of resin will double compared to the current situation.

The estimated yearly cost is ■<sup>29</sup>, including additional waste treatment cost.

An additional energy cost is anticipated of ■<sup>30</sup>. This is related to the evaporation of water rather than solvent from a viscous resin-water mixture (melted resin).

The total additional operational cost for PERC is ■<sup>31</sup>. (■)<sup>32</sup>

The total additional operational cost for Toluene is ■<sup>33</sup>. (■)<sup>34</sup>

The difference in PV between the two projects is due to the later start-time for Toluene and hence the fewer number of years of operation in the 2016-2034 period.

#### 4.3.3.3 Downtime Costs

Depending on the choice of the alternative for Use 1, there can be a period of time when Use 1 (de-waxing) is in operation while the resin recovery from the breaking-off water is not yet commissioned. During that period of time, the resin from the breaking-off process need to be disposed and replaced by new resin. This creates an additional raw materials cost, at a wax production volume of 27 mio yards/year of ■<sup>35</sup> and an additional waste treatment cost of ■<sup>36</sup>.

This alternative in combination with PERC as solvent for Use 1 therefore creates an additional cost of ■€/year<sup>37</sup>. The PV for this over the period 2016-2034 is ■<sup>38</sup> €. This is because the PERC-based alternative for Use 1 is estimated to be in operation 3.5 years earlier than the solvent-free extraction alternative for Use 2.

This alternative in combination with Toluene as solvent for Use 1 also creates an additional cost of ■€/year<sup>39</sup>. The PV for this over the period 2016-2034 is ■<sup>40</sup> €. The external de-waxing with Toluene is estimated to be in operation only two years earlier than the solvent-free extraction (because the Toluene alternative takes longer to implement than the PERC alternative), and hence involves shorter Use 2 downtime (but longer Use 1 downtime). The solvent extraction with Toluene off-site is expected to take one year longer compared to the on-site solution because

of the need to search for a new production site, more complex permitting and the overall higher complexity of the project.

#### 4.3.3.4 Conclusion on economic feasibility of Alternative 2.3

Table 16 summarises the preceding discussion and presents the estimated costs of implementing the solvent-free extraction alternative for Use 2. Two sets of costs are provided, depending on whether the alternative is implemented in combination with PERC or Toluene for Use 1. The total present value cost over the period 2016-2034 is estimated to be around ██████████€<sup>41</sup> for PERC and ██████████€<sup>42</sup> for toluene (discounted at 10%). In both cases, the largest proportion of the cost is accounted for by downtime, and the additional costs of resin consumption necessary while solvent-free extraction is not operational. We conclude that the alternative to switch to solvent-free extraction for Use 2 is economically not feasible.

Table 16: Overview costs Alternative 2.3<sup>43</sup>

Solvent free extraction with Resin		
Implementation time		- Development of solvent free extraction technology - Design and construction of installation
PERC	6 years	
Toluene	9 years	- Increased project complexity in combination with off-site cloth de-waxing with flammable solvent (Toluene) (Use 1)
Investment cost (PV)		- New equipment and installation of equipment - Additional complexity related to off-site de-waxing
PERC	██████████	
Toluene	██████████	
Impact on OPEX (PV)		- Increased loss of resin - Increased energy cost
PERC	██████████	
Toluene	██████████	
Transition cost (PV)		Additional cost of resin and waste treatment
PERC	██████████	- During 3.5 years
Toluene	██████████	- During 2 years
Total (PV)		
PERC	██████████	
Toluene	██████████	

Note

1. Number of production years in the period 2016-2034 is different for both options

#### **4.3.4. Risk reduction potential**

It is clear that this process is a solvent free extraction provides an opportunity to reduce the overall risk for human health in comparison with a solvent based process using hazardous substances. Therefore, this process has been part of the long-term process development program of Vlisco for many years.

The resin recovery performance of the solvent free extraction will not be as efficient as the current TCE based technology, meaning more resin will be lost into the environment (wastewater). The resin emissions will however have to be compliant with the environmental permit of Vlisco. The impact of increased resin into the environment has not been assessed at this stage.

##### Conclusion:

This process provides a reduction in the risks associated with the use of TCE because no solvent is used. Impact on environment, energy and use of resources has not yet been evaluated, so it is not possible to assess the impact on overall risk.

#### **4.3.5. Availability**

No new chemicals are involved in this alternative, and hence it is expected that the update of the exploitation permit, which will be required for this alternative, will be granted without the need for major revisions.

Even though conceptually the technology could work, it still needs to be developed and will not be ready by the TCE Sunset Date. It is expected that only some of the required equipment is standard available on the market.

The implementation time of a solvent free extraction alternative for Use 2 is highly dependent on the choices made for the alternative for the use of TCE in Use 1. The development and the implementation for solvent free extraction can take 6 to 9 years.

##### Conclusion:

The solvent free extraction alternative is not considered to be available to the applicant by Sunset Date.

#### **4.3.6. Conclusion on suitability and availability for Alternative 2.3**

The applicant does not consider this alternative as currently suitable or available. Although from a risk reduction perspective, this alternative could provide a positive option, its technical feasibility has not been proven. The technology is not mature enough to be implemented at Vlisco. In economic terms, this alternative is not feasible because of the required investment costs, and expected increase (with high uncertainty) in operational costs. If the implementation of the alternative for Use 1 takes less time compared to the time to implement this alternative, there will be an additional cost for the resin from Use 1 which cannot be recovered during the time in between the two project start-ups.

The process still needs further development and the equipment needs to be designed; no standard equipment is suitable for Vlisco. A development and implementation time of 6-9 years is envisaged.

#### **4.4. ALTERNATIVE 2.4: Rosin and solvent free extraction**

There is a high technical interaction between the use of rosin instead of resin (Use 1) and the use of solvent free extraction (Use 2). For this reason, this alternative can only be evaluated as a combined alternative. The discussion of this alternative is presented in section 4.3 (Alternative 1.3) of the AoA for Use 1 of this application dossier.



## 4.5. ALTERNATIVE 2.5: Switchable Solvent

### 4.5.1. Substance ID and properties

Switchable solvents<sup>32</sup> 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<sub>2</sub> the switchable solvent behaves like a traditional, low polarity, organic solvent. On exposure to CO<sub>2</sub> and in the presence of water, the solvent becomes hydrophilic and water miscible. Removal of the CO<sub>2</sub> 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<sup>33</sup> these solvents are known as Switchable Hydrophobicity Solvents (SHS).

In appendix D an example is provided of this technology.

### 4.5.2. 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.

Because it is solvent-based technology, it has the potential to be an alternative for both Uses 1 and 2. In Figure 8 the concept for the use of switchable solvents for extraction is shown.

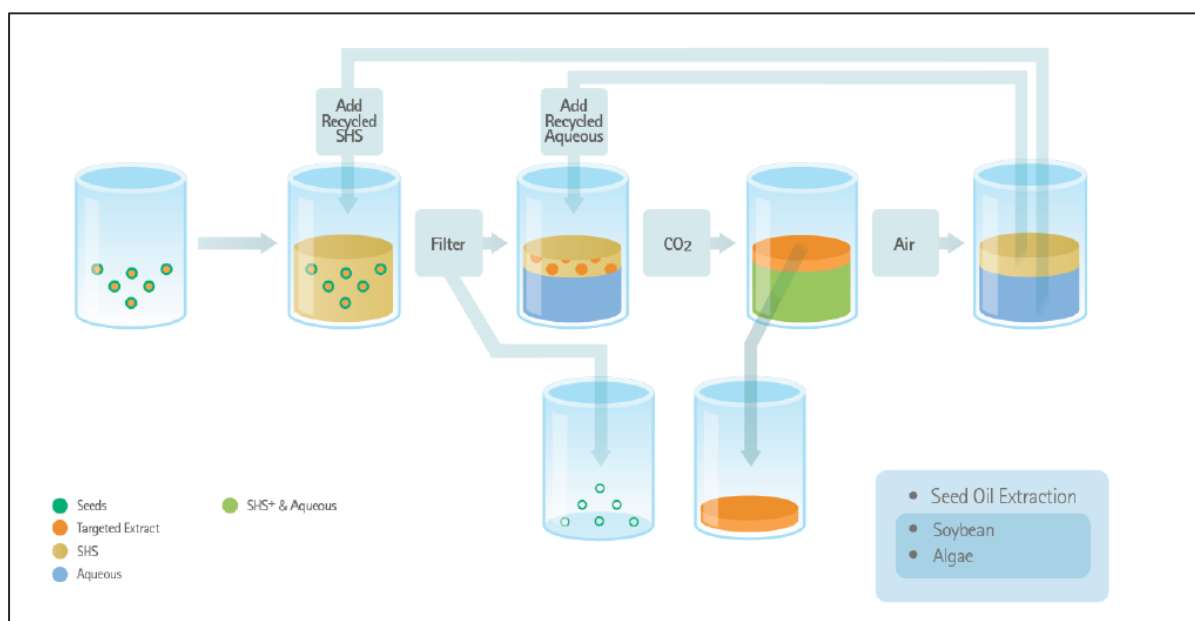


Figure 8: Switchable Solvent used in extraction applications (figure 3 in Appendix D)

<sup>32</sup> [http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-\\$5.48-million.php](http://www.greencentrecanada.com/news/GreenCentre-Canada-and-Switchable-Solutions-are-awarded-$5.48-million.php)

<sup>33</sup> “Alternative Solvents for Green Chemistry Second Edition RSC Publishing 2013, F.M. Kerton and R. Marriott

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 4.5.2.1).

The development time for this alternative has been estimated to be at least 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.

#### 4.5.2.1 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 9) is needed for the detailed planning of all R&D activities required.

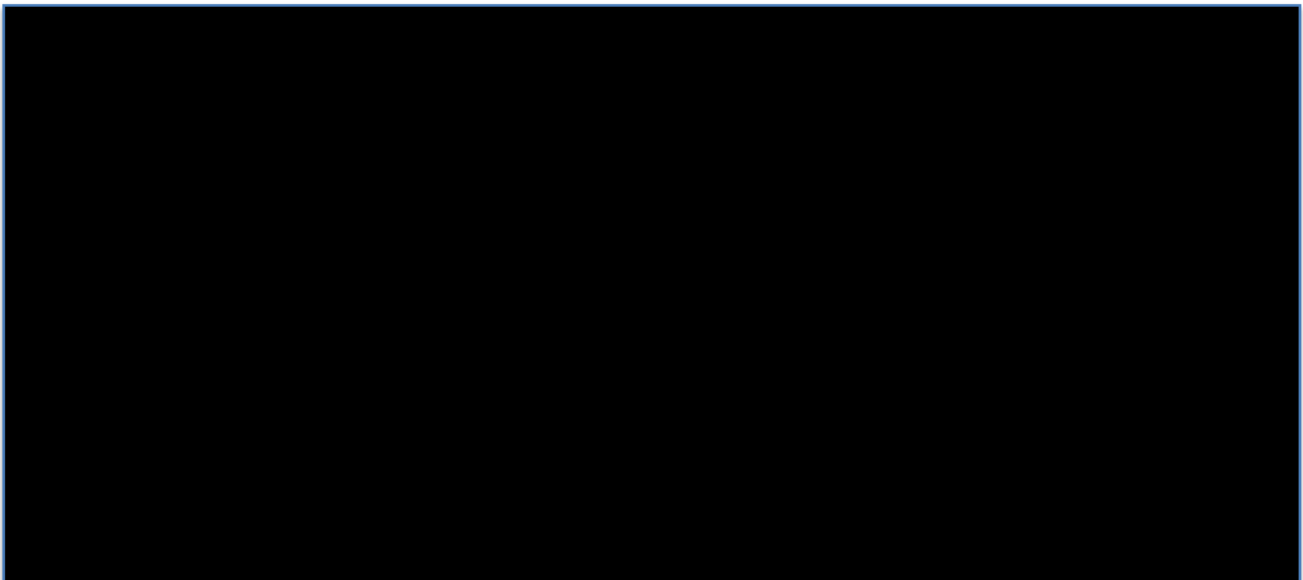


Figure 9: Switchable Solvent long-term development plan<sup>44</sup>

A break-down for a long term development plan for this alternative is provided in Table 17.

Table 17: Switchable Solvent long-term development plan<sup>45</sup>

Alternative for Use 1&2: Switchable solvent		Per step	Total (Years)
1.	Set up contracts with development partners	■	■
2	Long list of possible solvents	■	■
	Literature study		
	Lab scale tests		

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

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, cfr. 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 18:

Table 18: Stepwise approach for research, engineering and implementation of switchable solvents<sup>46</sup>

Step	Detail
1	█
2	█

Step	Detail
3	[Redacted]
4	[Redacted]
5	[Redacted]
6	[Redacted]
7	[Redacted]
8	[Redacted]
9	[Redacted]
10	[Redacted]
11	[Redacted]
12	[Redacted]

**4.5.2.2 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.

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 potential.

### 4.5.3. 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 recovery with switchable solvents will be available at the same time as Use 1 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.

#### 4.5.3.1 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 19 below:

Table 19: Breakdown of investment costs of Alternative 2.5<sup>47</sup>

Type of cost	Description	Cost estimate (€million)
Equipment	New extraction equipment.	■
Installation	Installation factor 0,6	■
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 <sup>34</sup> .	■
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	■
<b>Total</b>		■ PV ■

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 to recover the resin from the breakwater with a switchable solvent. Such an installation still needs to be designed and installed. It was estimated that this would take at least 12 years.

The estimated investment cost for this alternative has been estimated to ■ €<sup>48</sup> (PV ■ €)<sup>49</sup> for the part specific to Use 2.

#### 4.5.3.2 Operational cost

The potential reduction of operational costs because of reduced energy usage, has been taken into account in Use 1. The solvent and resin losses in the recycling processes will largely determine the economic feasibility. There is not sufficient information available to assess the total economical feasibility with confidence. However, no additional impact on operational costs is assumed for Use 2.

<sup>34</sup> 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](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf)

#### 4.5.3.3 Downtime Costs

The timing of this alternative is linked to the alternative 1.6 of Use 1. It is assumed that both alternatives are commissioned together. Therefore, there will be no additional transitional costs associated with downtime.

#### 4.5.3.4 Conclusion on economic feasibility of Alternative 2.5

The preceding discussion is summarised in Table 20. The estimated costs of adopting a switchable solvent alternative for Use 2 are ██████████<sup>50</sup> (discounted at 10%). This estimate is subject to high uncertainty. However, although a detailed economic feasibility study is not possible because of a lack of detailed information, this alternative is considered the only potentially feasible one, because of the prospect that it might generate reduced energy demand. The expected long development time, however, means that currently it could not be economically feasible, since its adoption would occur well beyond the TCE Sunset Date and would therefore imply the need for plant closure and/or increased resin consumption in the intervening period. The option could be economically feasible if it was adopted in a program with some other option (e.g. TCE or PERC), which allowed Vlisco's activities to continue, although the overall feasibility of this program is not guaranteed.

Table 20: Overview costs Alternative 2.5<sup>51</sup>

Alternative 2.5		
Implementation time	12+ years	- Development of technology - Design and construction of installation
Investment cost (PV)	██████████	- New equipment and installation of equipment
Impact on OPEX (PV)	███	- Possible benefit on OPEX included in Use 1 Alternative 6
Transition cost (PV)	███	- Assumed to be commissioned together with a Use 1 solution
Total (PV)	██████████	

#### 4.5.4. 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 with TCE. Switchable solvents have the potential to reduce the carbon footprint of the process through the reduction of energy consumption. Thus, reductions in risk in this respect might be expected to be associated with this option

#### 4.5.5. Availability

The technology of switchable solvents is not currently 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.

A development period of at least 12 years is currently envisaged.

#### **4.5.6. Conclusion on suitability and availability for Alternative 2.5**

The applicant does not consider this alternative as currently suitable or available. Significant development work is still required to make this alternative technically feasible. 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 characteristics.



## 5. OVERALL CONCLUSIONS ON SUITABILITY AND AVAILABILITY OF POSSIBLE ALTERNATIVES

### 5.1. ALTERNATIVES for Use 2

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. (Use 1 estimates are presented and discussed in the AoA for that use.) 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 have 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. 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. (Equivalent costs estimated from the social perspective are presented in the accompanying SEA.) The resulting estimates are presented in Table 21.

Table 21: Cost (PV) adopting alternatives to the use of TCE<sup>52</sup>

Option for Use 1 and Use 2	Use 1 (mio €)	Use 2 (mio €)	Total (mio €)
PERC	■		■ (94%)
PERC		■	
PERC	■		■ (100%)
Solvent free extraction		■	
Flammable solvent	■		■ (101%)
Flammable solvent		■	
Flammable solvent	■		■ (112%)
Solvent free extraction		■	
Rosin	■		■ (110%)
solvent free extraction		■	

Option for Use 1 and Use 2	Use 1 (mio €)	Use 2 (mio €)	Total (mio €)
Switchable solvent	■		■ (109%)
Switchable solvent		■	
RSP			■ (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.

In the Table 21, the period to calculate the PV is 2016-2034. This is period that typically would be taken for the evaluation of large capital projects. A second calculation was done over the review period 2016-2027 to be used in the SEA. The ranking and the overall conclusions stay the same.

It can be seen from Table 21 that a switch to RSP is estimated to be by far the most costly option, with a net present cost of over ■ €<sup>53</sup> 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 would be 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 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 ■ €<sup>54</sup> 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 10.

Scenario: Combination Use 1 & Use 2		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
PERC Use 1&2	Use 1			2,5									
	Use 2				4								
PERC + Solvent free extraction	Use 1			2,5									
	Use 2						6						
Flammable solvent on site	Use 1						6						
	Use 2						6						
flammable solvent (off site) + solvent free extraction	Use 1							7					
	Use 2									9			
Rosin + Solvent free extraction	Use 1									9			
	Use 2									9			
Switchable solvent	Use 1												12
	Use 2												12
RSP				1									

Figure 10: 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 – in practice, this is likely to underestimate the cost because Vlisco will incur additional costs associated with closure (e.g. redundancy payments for workers), or some costs will not be avoidable through closure (e.g. overheads). However, the high cost associated with the loss of each year's worth of profit (estimated at around ████████€<sup>55</sup> in 2014 terms) and the costs of rehiring and training staff on the restart of operations, accounts for the high estimated total cost of implementing these options. It also emphasises the importance of implementation times to the overall cost of alternatives to TCE for Use 1.

Note that where costs appear higher for apparently the same solvent free extraction option, this is because it is expected that implementing this option for Use 2 will take longer than the associated alternative for Use 1 – this difference implies a temporary and costly increase in resist consumption while solvent free extraction is brought on stream.

Because of the relatively short times for implementation of PERC-based alternatives for Use 1, the costs of the 'PERC' and 'PERC + solvent free extraction' options do not include as much cost in terms of lost profit. However, these savings are offset by the fact that Vlisco would propose not to reduce permanent employment of staff during the implementation of these options, so as to avoid the need to rehire and retrain staff when they were reemployed. These two countervailing effects somewhat offset each other, so that the overall costs of the options are between ████████€<sup>56</sup>. A PERC-based option for Use 1 (with PERC or solvent free extraction for Use 2) is 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 ████████€<sup>57</sup> 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 under ████████€<sup>58</sup> in present value terms over the period 2016-2034. This makes it the second 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 12 years (and possibly longer), with associated loss of profit (among other costs). This option is clearly not economically feasible or affordable under these circumstances. However, as discussed in Section 4, the switchable solvent alternative is the only option which is expected to be able to generate 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) would be just over 5 mio €. These costs (although very uncertain) might fall further if implementation periods could be shortened, to the extent that the investment could actually 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 4.5.2.1, a description is provided of a long term development plan for an alternative to TCE (see Figure 11). 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.

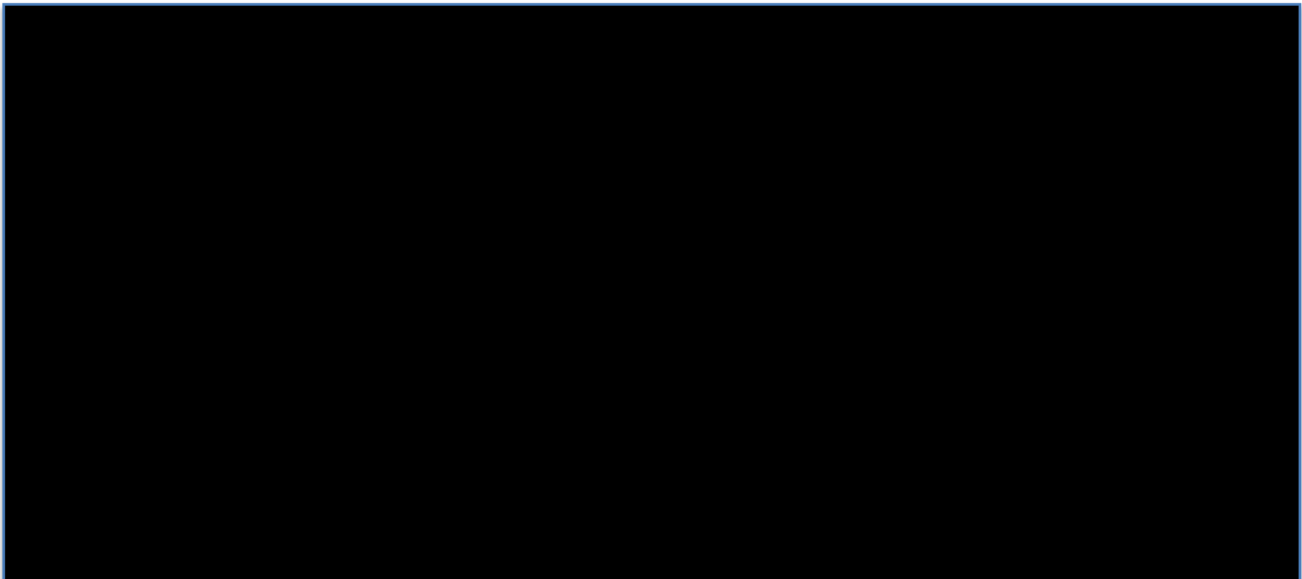


Figure 11: Switchable Solvent long-term development plan<sup>59</sup>

## **APPENDIX A: OVERVIEW KNOWLEDGE DOCUMENTS TCE ELIMINATION**

Author: T. Hofs

In this document the documents as delivered by Vlisco to Iv-Industrie (up to 30-05-2013) are categorized.<sup>60</sup>

■	██████████	■	██████████	██████████	██████████	██████████	██████████	██████████	██████████	██████████
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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.

List of solvents <sup>61</sup>:

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

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

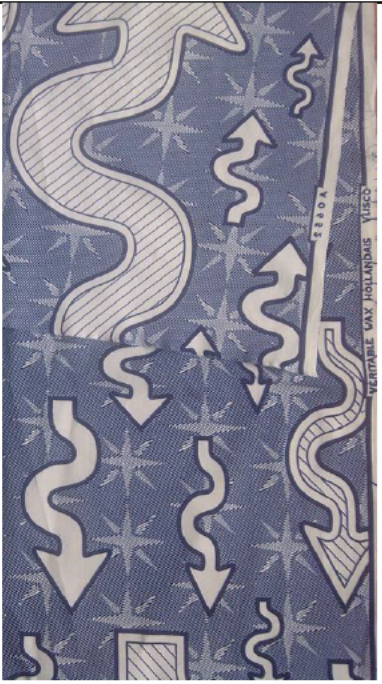
Vlisco has been operating for 168 years and over time refined/improved the quality of the product and process. It is important to illustrate some of these key design features made possible using a wax process and TCE relative to other techniques such as screen printing. Currently, it is not possible to replace TCE and/or resin without compromising the quality of the products being produced.



### Key Vlisco design features


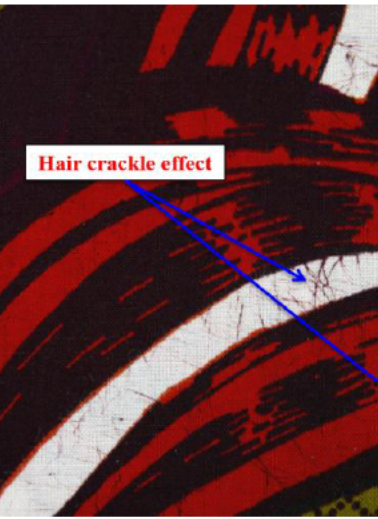
- Designed indigo dyeing
- Broad colour range; vivid and bold colours (reactive, azoic & phtalogene dye)
- A controlled matching of front and back: same colour or half tones colours
- Non repeating unique bubbling patterns originating from the design
- Crackle effect
- A soft appearance of the design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

Table 22 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 22: Key Vlisco design features for consumers<sup>62</sup>

Key features	Illustration	Basic description
Substrate		Cotton, for wear comfort in tropical area's
Designed indigo dyeing		<p><b>Desirable effects for consumers</b></p> <p>Indigo has a large cultural significance in many African countries and has been used in African cloth-making since the 16<sup>th</sup> century.</p> <p><b>What is it and how is it created?</b></p> <p>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.</p> <p>A large part of the Vlisco products are dyed with Indigo as base colour.</p> <p><b>Relationship with TCE</b></p> <div style="background-color: black; width: 100%; height: 40px; margin-top: 10px;"></div>

Key features	Illustration	Basic description
<p>Broad colour range</p>		<p><b>Desirable effect for the consumers</b></p> <p>A wide range of deep and vivid colours with superior properties of resistance to wear (wash, light, rubbing, perspiration).</p> <p><b>What is it and how is it created</b></p> <p>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 &amp; 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.</p> <p><b>Relationship with TCE</b></p> <p>[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..</p>
<p>Matching of front and back</p>		<p><b>Desirable features for consumers</b></p> <p>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.</p> <p><b>What are half tones and how are they created?</b></p> <p>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.</p> <p><b>Relationship with TCE</b></p> <p>[REDACTED]. The resin leads to the use of a solvent to completely remove the resin from the cloth.</p>

Key features	Illustration	Basic description
<p>Non repeating unique bubbling patterns</p>		<p><b>Desirable features for consumers</b></p> <p>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)<sup>35</sup>.</p> <p><b>What is bubbling and how is it created?</b></p> <p>[REDACTED]</p> <p><b>Relationship with TCE</b></p> <p>[REDACTED]</p>
<p>Crackle effect</p>		<p><b>Desirable features for consumers</b></p> <p>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 cracking.</p> <p><b>What is the crackle effect and how is it created?</b></p> <p>[REDACTED]</p> <p>After removal of the resin these cracks appears in the cloth only at positions where the resist was applied</p> <p><b>Relationship with TCE</b></p> <p>[REDACTED]</p>

<sup>35</sup> 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
		<div style="background-color: black; width: 100%; height: 50px;"></div>
Soft appearance		<p><b>Desirable features for consumers</b></p> <p>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.</p> <p><b>What is the soft design and how is it created?</b></p> <div style="background-color: black; width: 100%; height: 80px;"></div> <p><b>Relationship with TCE</b></p> <p>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.</p>

Table 23: The differences between a Vlisco wax product and a screen printed product<sup>63</sup>

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, Azoic, Phtalogene, mix Azoic/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 [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.

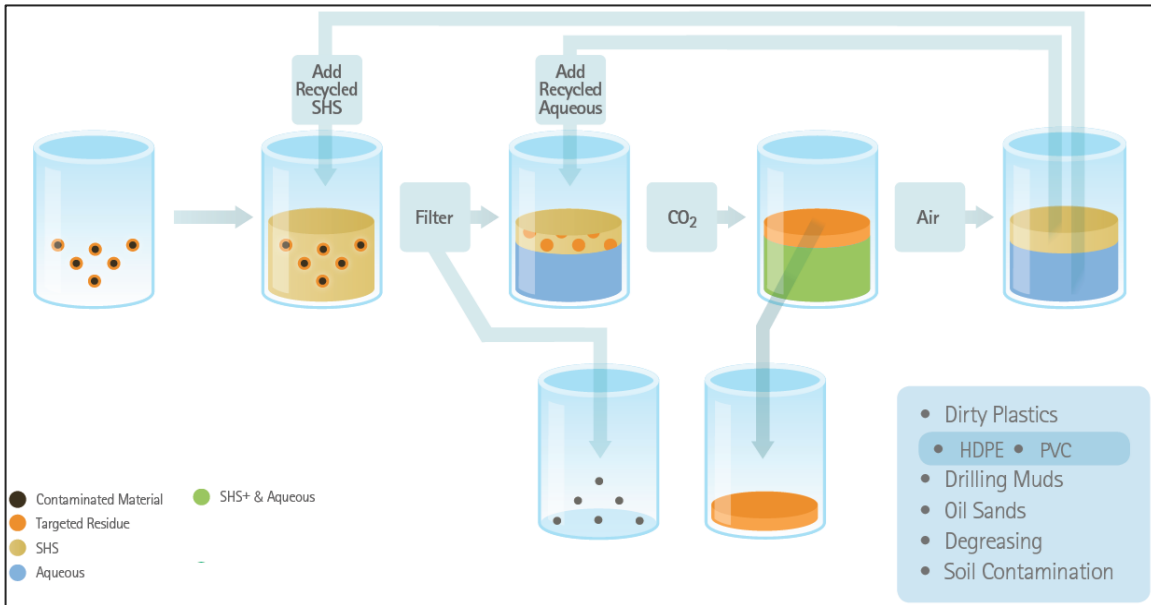
Representing a breakthrough in organic solvent technology the solubility characteristics of our solvent systems can be reversibly manipulated on-demand via the introduction or removal of carbon dioxide (CO<sub>2</sub>). In the absence of CO<sub>2</sub> our SHSs behave like a traditional low polarity organic solvent. On exposure to CO<sub>2</sub> and in the presence of water our solvents become extremely hydrophilic and water miscible. Removal of the CO<sub>2</sub> 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<sub>2</sub> and water.

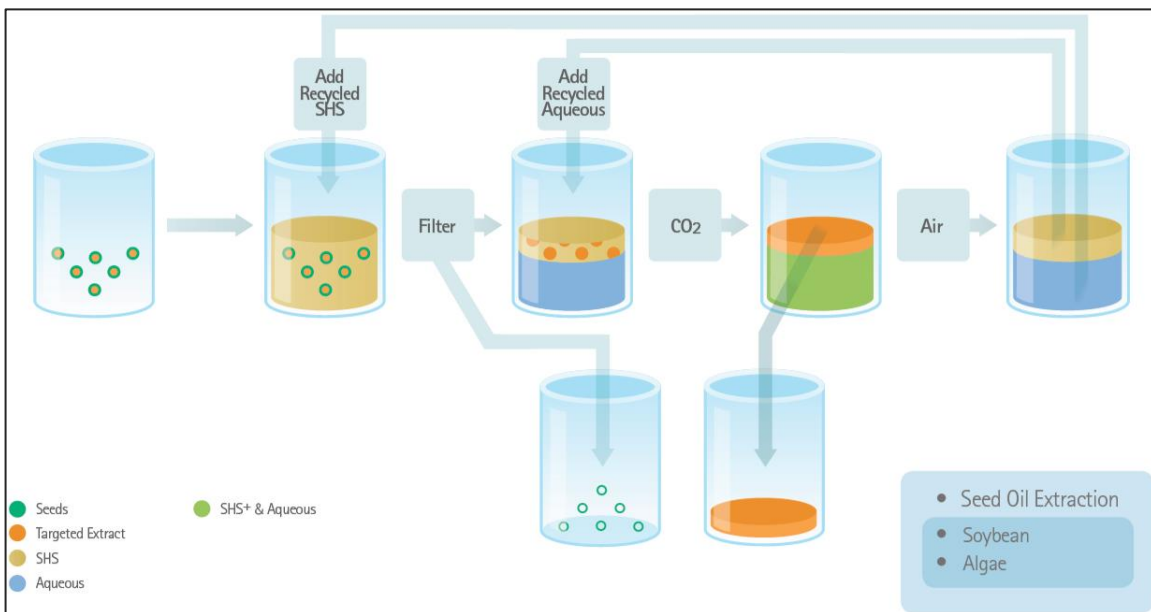
The low energy nominal temperature and pressure manipulation of this breakthrough solvent system can enhance a number of industrial processes including:

- 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 Lowell. A database has been created by Surface Solutions Laboratory.  
[http://www.cleansolutions.org/?action=solvent\\_replace](http://www.cleansolutions.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/>



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