Format for
ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

Legal name of applicant(s):	Rimex Metals (UK) Ltd
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Use title:	Use of Chromium trioxide as an oxidising and hardening agent in the manufacture of coloured stainless steel
Use number:	1

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List of Abbreviations

Abbreviation	Description
AfA	Application for Authorisation
AoA	Analysis of Alternatives
APF	Assigned Protection Factor
CBAM	Carbon Border Adjustment Mechanism
CIE	Commission on Illumination
CMR	Carcinogen, Mutagen or toxic for Reproduction
Cr(VI)	Hexavalent chromium, also known as chromium trioxide
CSR	Chemical Safety Report
CSS	Coloured Stainless Steel
CT	Chromium trioxide
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortisation
ERC	Environmental contributing scenario
ES	exposure scenarios
EU	European Union
GB	Great Britain
HCl	Hydrochloric acid
HRA	Hot rolled & annealed
IPPC	Integrated Pollution Prevention and Control
LEV	local exhaust ventilation
NUS	Non-use scenario
PPE	personal protective equipment
PROC	Process category
PV	Present Value
PVD	Physical Vapour Deposition
R&D	Research & Development
RCR	risk characterisation ratios
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
RPE	respiratory protective equipment
RR	Review Report
SEA	Socio Economic Analysis
SME	Small and medium
STM	Surface Treatment of Metals and Plastics
STP	sewage treatment plant
SVHC	Substance of Very High Concern
Ti	Titanium
TWG	Technical Working Group
UK	United Kingdom
UK BAT	UK Best Available Techniques
UV	Ultraviolet
WCS	Worker contributing scenario

DECLARATION

We, the Authorisation Holder, are aware of the fact that further evidence might be requested by HSE to support the information provided in this document.

Also, we request that the information blanked out in the “public version” of the Analysis of Alternatives and Socio-economic Analysis is not disclosed. We hereby declare that, to the best of our knowledge as of today ([20 March 2026]), the information is not publicly available, and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signature ____________________

Date, Place:

20 March 2026, Enfield

Tim Childs

Managing Director

Rimex Metals (UK) Ltd

1 Summary

1.1 Description of the use and importance of chromium trioxide

Chromium trioxide (EC No.: 215-607-8, CAS No.: 1333-82-0) is used for the manufacturing of Coloured Stainless Steel (CSS) under the INCO process by Rimex Metals (hereafter referred to as Rimex). The CSS end product is used in various applications, most notably in architecture (external and interior cladding, columns, doors, signage and street furniture), lifts and escalators, but also in transport (skirting on rail cars, kick plates and doors), refrigeration and food service (refrigeration doors, coldstores, cooker hobs) and other engineering applications.

Rimex are submitting this Review Report (RR) and applying for an authorisation to ensure continued use of chromium trioxide. This RR covers one use for chromium trioxide used as an oxidising and hardening agent in the manufacture of CSS. The manufacturing plant of Rimex, based in Enfield, UK produces a number of coloured and uncoloured stainless steel products, such as patterned/textured cold rolled finishes (also known as the rigidised finishes), vibration polishes, bead blast finishes and etched finishes along with a smaller volume of non-stainless steel products (e.g. aluminium).

1.2 Efforts to identify alternatives

Since the submission of the original application Rimex have continued efforts to identified alternatives. Although Rimex is a SME with limited research capabilities and a modest budget for R&D work, Rimex has made significant efforts towards the identification of potential alternatives for CrO_3 and the INCO process. Efforts included sponsoring two PhD studies over a period of 7 years. These studies concluded that no process was able to rival the aesthetic quality and mechanical and environmental performance of the INCO process using chromium trioxide and that no alternative was suitable for replacement of chromium trioxide in INCO colouring.

As described in the original and again within this application, Physical Vapour Deposition (PVD) CSS has so far shown significant technical shortcomings as well as economic feasibility challenges.

Rimex continues to keep up to date with technological and alternative developments.

1.3 Requested review period

Rimex are seeking a 25-year review period. This review period is requested for several reasons. A 25-year review period would provide market certainty to existing downstream users of CSS products. Rimex have already undertaken significant R&D, it is unlikely that the situation in regard to alternatives will change in the long term while an extra-long review period will allow Rimex and the sector to continue research into identifying potential alternatives.

A 25-year review period also aligns with very long investment cycles and minimum lifetime (minimum of 20 years) of INCO CSS manufacturing lines.

This review period would also give Rimex the confidence and business case to commit to investing in upgrading several aspects of the Enfield site (or an alternate site should that arise) and the manufacturing processes which could be included as a condition within the Authorisation Decision.

1.4 Applied for Use and Non-use scenarios

CrO_3 is a strong oxidiser, which, along with sulphuric acid, works to form a thin film of chromium (III) oxide (Cr_2O_3) on the surface of the stainless steel, colouring it through thin film interference (first role of the substance). As a second step, the coloured film is subjected to a cathodic treatment in another acidic solution containing CrO_3, which 'hardens' the film (second role of the substance). CSS hardened in this manner has much greater resistance to scratching and marking and the lustrous appearance of CSS is not diminished. This is the so-called INCO process and Rimex is one of only three companies in the Europe, and the only one in the UK that manufactures CSS using this process. The consumption of CrO_3 by Rimex is at the lower end of the 1-10 t/y range at #A tonnes in 2023; it is expected to marginally increase in the coming years due to an envisaged increase in sales of INCO-made CSS.

1.5 Human health and environmental impacts from the continued use of chromates

Estimates of the excess lifetime cancer risks for both workers and humans via the environment are calculated in the CSR. In total, at Rimex's UK site, there are a total of 5 directly and 17 indirectly exposed workers.

Combining these figures with exposure estimates leads to an estimated 0.02 additional fatal lung cancer cases and 0.01 would be additional morbidity cases. These translate to monetised residual risks for exposed workers of around £0.9 to 1.3 million in total over the length of the requested 25-year review period (end of 2027-end of 2052).

For humans via the environment, it is estimated that there would be an additional 1.09 fatal cancer cases and 0.29 morbidity cases. This equates to monetised risks of around £1.2 to 1.7 million in total over the length of the requested 25-year review period (end of 2027-end of 2052).

Combining the two values together results in estimated, monetised residual risks from the continued chromium trioxide formulation activities of ca. £2.1 to 3.0 million in total over the 25-year review period.

No environmental assessment was carried out as chromium trioxide has not been identified as a substance of very high concern in relation to its effects on organisms in the environment. Furthermore, the release of chromium trioxide from Rimex to environmental compartments from the activities is also low due to the combination of reduction methods. Any hexavalent chromium (Cr(VI)) from chromium trioxide is expected to reduce to Cr(III) under most environmental conditions, thus limiting any potential impact of Cr(VI) to the immediate vicinity of the source.

1.6 Environmental costs from a refused authorisation

In the non-use scenario, environmental emissions from transport are expected to increase due to the greater distances CCS will need to be transported between the non-UK manufacture of CCS and the end customer. In the non-use scenario where PVD CCS may replace INCO CSS, this form of CCS also has higher energy and water consumption requirements.

1.7 Balance between benefits and costs

The aggregated present value benefits from the continued use of chromium trioxide as an oxidising and hardening agent in the manufacture of CCS are estimated at £125,000 to £179,000 (annualised)

The resulting benefit-to-cost ratios are large due to the potential lost producer surplus and the low human health risks due to the limited number of workers exposed, the risk management measures in place and the low release from Rimex's site.

1.8 Economic and social costs of a refused Authorisation

In conclusion, the most likely non-use scenario would be closure of Rimex Enfield site, with importing of INCO CSS and PVD CSS from outside of the UK likely to replace UK INCO CSS. It will also no longer be financially viable to maintain the Enfield site, and it is not cost effective for Rimex to manufacture PVD CSS. Customers will either import INCO CSS from another site in Europe, Asia or the USA, or switch to PVD CSS.

2 Aims and Scope of the Analysis

2.1 Introduction

This combined Analysis of Alternatives (AoA) and Socio-Economic Analysis (SEA) has been prepared on behalf of Rimex Metals (UK) Ltd (hereafter referred to as Rimex) and updates the assessment from the original Applications for Authorisation (AfA) for this Review Report (RR). This RR covers the use of chromium trioxide (CT) as an oxidising and hardening agent in the manufacture of coloured stainless steel (CSS).

This RR has been conducted from the perspective of Rimex, a user of CT, with consideration of feasibility of alternatives to both Rimex and throughout the supply chain.

Chromium trioxide (CAS No. 1333-82-0; EC No. 215-607-8) was added to Annex XIV (Authorisation List) due to its carcinogenic and mutagenic properties, as outlined in the Chemical Safety Report (CSR). These harmful effects, particularly for hexavalent chromium compounds like CrO_3, have no identified safe threshold. Therefore, this AoA/SEA aims to demonstrate the benefits of continuing to use chromium trioxide in the manufacture of CSS products by Rimex, which are sold in both GB and non-GB markets.

Rimex has been producing surface finishes on stainless steel since 1959 and operates plants in the UK, USA, Germany, France and Australia. Its production expertise ensures high standards in material management and quality control (RIMEX Metals Group, 2012). Rimex's finishes include:

- Patterned/textured cold-rolled finishes (rigidised finishes) like 2WL, 5WL, 5-SM, 6WL, 6-OM, 7GM® Linen, Squares, Treadplate
- Coloured stainless steel
- Vibration-polished finishes
- Bead-blast finishes
- Etched finishes

Rimex's products are widely used in architectural, engineering, machinery, refrigeration, elevator, and transit industries (RIMEX Metals Group, 2012).

The Rimex INCO process, is used to produce Rimex's ColorTex® product range. The INCO process is an electrochemical process used to colour stainless steel by modifying the thickness of the natural oxide layer on the surface. This modification creates a thin interference film that produces a range of colours through the interaction of light with the film's thickness.

2.2 Aims of the combined AoA and SEA document

Rimex have no qualified (from a technical perspective) and economically feasible alternatives which can be fully implemented in their manufacture of CCS before the expiry of the original authorisation. Therefore, they must continue to use CT as an oxidising and hardening agent in the manufacture of CCS.

CCS is used in several different applications such as in architecture, lifts and escalators, transport, refrigeration and food service and other engineering applications. The CCS achieves the following properties: increased resistance to scratching and marking; a wide palette of uniform stable and bright colours; good wear and ultraviolet (UV) resistance and a combination of colours and patterns on stainless steel that permits an increased range of produced products.

Considering this, the aim of this RR is therefore to allow the use of CT in the manufacture of CCS beyond the end of the existing review period which expires on 21 September 2027. The RR demonstrates the following:

- The technical and economic feasibility, availability, and challenges in identifying an acceptable alternative to the use of chromium trioxide, which does not compromise the functionality and reliability of the stainless steel;
- The R&D that has been carried out by Rimex through the funding of two PhD students towards the identification of feasible and suitable alternatives for CT has not been successful;
- The socio-economic impacts that would arise for UK if the applicant was not granted re-authorisations for the continued use of CT over an appropriately extra long review period; and
- The overall balance of the benefits of the continued use of CT to the risks to human health from the carcinogenic and reprotoxic effects that may result from exposures to CT.

2.3 The parent Application for Authorisation

This combined AoA/SEA covers only the use of CT in a flake form in the manufacture of CCS:

- Chromium trioxide (EC 215-607-8, CAS 1333-82-0)

CT was included in Annex XIV of REACH[1] (Entry No. 16) due to its carcinogenic (Cat. 1A) and mutagenic (Cat. 1B) properties. Authorisations granted for the continued use of CT in the manufacture of CCS were approved under EU REACH and grandfathered across into UK REACH after the UK's exit from the European Union. The parent application, originally submitted to ECHA is summarised in **Table 2-1**.

Table 2-1: Overview of the Initial Parent Application for Authorisation

ECHA Application ID/Authorisation number	UK REACH Authorisation number	Substance	CAS # / EC#	Parent Authorisation – Authorised Use
0056-01 REACH/17/12/0	02UKREACH/17/12/0	Chromium trioxide	1333-82-0 / 215-607-8	Use of chromium trioxide as an oxidising and hardening agent in the manufacture of CCS

2.4 Introduction to the stainless steel sector

2.4.1 Types of stainless steel

Stainless steel is an alloy containing various metals, primarily iron, chromium, and often nickel, molybdenum, and other elements. This combination gives the material excellent resistance to corrosion and heat. The first patent for stainless steel production was granted in 1912 (ISER, 2012).

Austenitic stainless steels are the most commonly used type, characterised by a face-centred cubic crystal structure. They typically contain 16–25% chromium and may also include nitrogen in solution, both of which contribute to their high corrosion resistance (ASM International, 2008). The nickel content in austenitic stainless steels can vary widely, ranging from 1-3% in special engineering steels, 8-14% in standard stainless steels, 15-40% in specialised engineering alloys, and 40-90% in alloys for the aerospace and electronics industries (Nickel Institute, 2013).

[1] https://www.legislation.gov.uk/eur/2006/1907/annex/XIV

Other types of stainless steel include ferritic and martensitic grades. Ferritic stainless steel contains 10.5–27% chromium and only small amounts of nickel, with most compositions including molybdenum, and sometimes aluminium or titanium. Martensitic stainless steel, on the other hand, typically contains 12–14% chromium, 0.2–1% molybdenum, less than 2% nickel, and 0.1–1% carbon. It is quenched and magnetic (ASM International, 2008).

A steel grade is classified as "stainless" if it contains a minimum of 10.5% (w/w) chromium (12% in some sources) (SPP Inc., n.d.; ISSF, 2013). The chromium reacts with atmospheric oxygen and moisture to form a very thin, self-repairing layer of trivalent chromium oxide (Cr2O3) on the surface. If damaged, the chromium in the alloy quickly reacts with air, resealing the surface (ISSF, 2013). Additional alloying elements, such as nickel and molybdenum, can be added to enhance specific properties, but it is chromium that forms and stabilises the protective layer.

There is no single type of stainless steel, but rather a wide range of grades, each suited for different applications. These generally fall into one of four main families: austenitic, martensitic, ferritic, and duplex. Austenitic stainless steels are the most widely used family, and the applicant primarily works with this type. **Table 2-2** summarises the main categories of stainless steel.

Table 2-2: Main Categories of Stainless Steel Grades

Stainless Steel	Cr (%)	Ni (%)	Other (%)	Comments
Austenitic	16-26	6-12	C: ≤ 0.8 Mo	Most commonly used, especially for construction applications like roofing or cladding[2]. Better corrosion resistance than Martensitic or Ferritic steels.
Martensitic	10.5-18	varies	C: 0.2-1.0	Ni is used in some grades. Superior strength compared to austenitic and ferritic but worse corrosion resistance.
Ferritic	12.5-17	0		
Duplex	18-26	4-7	Mo: 0-4 Cu	Combination of austenitic and ferritic steel. Good corrosion resistance with greater strength than austenitic. Still under development.

Source: (EUROFER, 2010)

2.4.2 Stainless steel finishes

Stainless steel produced through hot or cold rolling is referred to as having a "mill finish." This type of stainless steel has a grey colour with varying degrees of reflectivity. Reflectivity, or reflectance, is a property of materials based on their reflection coefficient. The reflection coefficient, determined by the Fresnel equations, can be expressed as a complex number and is always positive. According to the International Commission on Illumination (CIE), reflectivity differs from reflectance in that it applies to thick reflecting objects. Reflectivity can also be interpreted as the fraction of electromagnetic power reflected from a specific sample. The reflectance spectrum, or spectral reflectance curve, plots

[2] Berggren et al., Release of Chromium, Nickel and Iron from Stainless Steel exposed under atmospheric conditions and the environmental interaction of these metals, Eurofer, October 2004.

reflectance as a function of wavelength, which can result in different reflected colours that may even change with temperature.

The production process of stainless steel depends on whether pickling (acid treatment to remove scale) or annealing (heating and cooling to improve ductility) has taken place. Mill finishes serve as the starting material for producing textured stainless steel products using techniques such as mechanical abrasion, pressing, rolling, bead blasting, or (electro)chemical colouring. These specialised finishes are often used in construction and architectural applications (Kosmac, 2011).

Mechanical finishes involve brushing the mill surface using oil-coated emery or dry brushing with grit belts or fibre brushes to achieve a smooth, polished appearance without chemical transformation. Fine polishing lines may be visible depending on the grit size or brush fibre width. Examples of such finishes include hairline, angel hair, swirl, and distressed finishes (SSINA, 2013). Polishing can also be achieved through electrochemical processes, such as electropolishing, which smooth the surface by depositing material in the "troughs" and removing it from the "peaks" of the steel surface. While the resulting surface may not have the same reflectivity as one polished mechanically, it can offer higher corrosion resistance.

Patterned finishes, which exhibit repeating patterns (e.g., checkerboard), applied to one or both sides of the sheet and are created through rolling with patterned rolls. These finishes are often used on large surfaces, particularly for cladding applications.

Low-reflective surfaces on stainless steel can be achieved by abrasive (bead) blasting on mill-finished stainless steel using non-reactive materials such as ceramics, aluminium oxide, or glass. This treatment, particularly on austenitic steels, has the added benefit of work-hardening the material.

In **Table 2-3** a description of different stainless steel finishes are outlined.

Table 2-3: Stainless steel strip, sheet and plate

Code for Mill Finish	Description	Remarks
HRA	Hot rolled & annealed	Industrial heat-resisting and material handling applications, scale impairs corrosion resistance
No 1	Hot rolled, annealed and descaled	Generally used when smoothness and uniformity of finish are not important
2D	Cold rolled, annealed and descaled	A uniform, matt finish
2B	Cold rolled, annealed, descaled and skin passed	A smooth finish for general applications
BA	Bright cold rolled finish. Retained by final annealing in a controlled atmosphere furnace.	Mirror finish

Source: International Stainless Steel Forum-Surface Treatment (Link)

2.4.3 Coloured stainless steel

One of the special finishes available for stainless steel is colouring. Stainless steel can be coloured through several methods, including electrochemical colouring, sputtering, plating, and resin-based paints. The scratch resistance, appearance, and colour stability of these methods can vary significantly, and these factors should be considered when making a selection. While some processes can enhance corrosion resistance, they should not replace choosing an appropriate grade of stainless steel for the specific environment (SSINA, 2013).

Electrochemical colouring (also known as light interference or INCO colouring) involves immersing stainless steel in a hot acid solution while applying an electrical current. This process thickens the transparent chromium oxide film on the surface, enhancing corrosion resistance and altering the way light is reflected. A wide range of colours is available, including gold, bronze, purple, blue, red, black, and green. The colour is durable and can be applied uniformly or varied for a rainbow effect, though slight variations in hue may occur (SSINA, 2013).

Because the colour is transparent, the underlying finish remains visible. Combining different colours and finishes can create unique effects. Colour can be selectively removed by etching, polishing, or engraving. While fingerprints can be wiped off smoother finishes, they may become permanent on rougher surfaces. The colour is susceptible to damage from scratching and cannot be repaired. However, when applied over a coined or embossed finish, the colour in the raised areas can be protected and has proven effective in high-traffic areas (SSINA, 2013).

Various techniques for colouring stainless steel operate on different principles. **Table 2-4** provides a comparison of the performance and selection criteria for CCS. Note that the table reflects general comparisons and may not represent the applicant's specific perspective, as assessments can be subjective.

Table 2-4: Application performance comparison and selection criteria of CCS

Coloured finishes	Applications				Selection criteria	
	Wall panels and trims	Roofing	Signage, art, decorative panels	High traffic areas	Repairable	Fewer visible scratches fingerprints
Electrochemical	P	P	P			
Embossed, electrochemically coloured and buffed (highlighted)	PPP	P	P	PPP	PPP	PPP
Sputtered	PP	P	P	PPP	P	
Terne-coating	P	P				
Other metal plating	P	P	P			
Paint	P	P	P	P	P	

Source: Adapted from (SSINA, 2013)

2.4.4 Stainless steel applications

Stainless steel is widely used in civil engineering and architecture, but its applications extend across various other industry sectors, including construction, automotive equipment, medical tools, transportation vehicles, appliances, and cooking utensils. Its resistance to corrosion and weathering, combined with its durability, makes it a versatile material for many industries (Francis and Byrne, 2021)[3].

The following provides a general overview of the diverse range of products derived from stainless steel production. Sectors or applications where CCS is in demand are highlighted in bold.

[3] Metals | Free Full-Text | Duplex Stainless Steels—Alloys for the 21st Century (mdpi.com)

- Automotive parts
- Baggage handling equipment
- Baking equipment
- **Bridges**
- Cargo containers
- Chemical processing equipment
- Closets
- Coffee maker
- **Column cladding sheet**
- Commercial kitchen
- Cookware
- Counter tops
- Dairy handling equipment
- **Decorative building material**
- Dishwasher drums
- Elevator cabins
- **Entry doors**
- **Escalators**
- **Facades/feature walls/decorative walls**
- Fire doors
- Fireplace fronts
- Flatware
- **Floors, balustrades & staircases**
- Furniture
- Hardware
- Hospital equipment
- Jewellery
- Kitchen cabinets/
- cupboards
- Kitchenware
- **Lift panels**
- **Metal roofing**
- Microwave oven interior
- Monuments and sculptures
- Nuclear vessels
- Public facilities
- Rails
- Refrigerator panels
- **Roofing materials**
- Signs and nameplate
- Sinks
- Splash backs
- Storage containers
- Storage tanks & pipes
- Stove tops
- Surgical instruments
- Tableware
- Vehicle frames
- Washing machine interior
- Water treatment equipment
- Window frames

Building design has become a critical factor in addressing the challenges of resource scarcity and climate change. In this context, there is growing recognition of the long-term benefits of stainless steel. For example, stainless steel roofs or building exteriors can reduce the solar heating effect, lowering the demand on air conditioning systems. Its corrosion resistance also ensures low maintenance and a long lifespan, making it an ideal choice for sustainable construction. Additionally, stainless steel is fully recyclable (Team Stainless, 2013).

Due to its strong environmental credentials, stainless steel stands out as a uniquely sustainable material. Its recyclability allows it to be reused indefinitely without loss of quality, meaning it can continually be recycled and remain usable as steel forever (Pradhan and Matawale, 2023).

2.5 Overview of the coloured stainless steel process

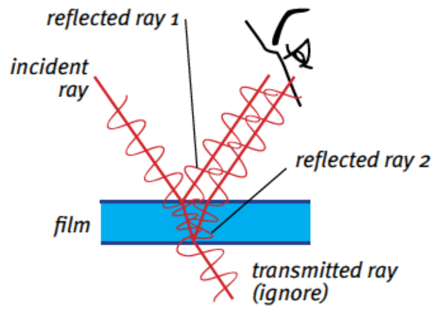
As noted in previous sections, stainless steel is used in buildings particularly for decorative functions in building architecture. The colouring of stainless steel can be categorised into three groups, electrochemical, non-electrochemical and laser colouring[4].

The most widely adopted colouring technique in industry is a two-stage electrochemical process, known as the INCO process. This method uses chromic-sulphuric acid baths to create a thin interference film on the stainless steel surface via immersion (Alliott et al., 2022)[5]. In the first step of the INCO process, chromium trioxide is as an oxidiser and hardening agent and along with sulfuric acid to apply a thin film on the surface of stainless steel, colouring it through the interference with the visible spectrum of light (thin-film interference).

4 Laser colouring can be achieved through either electrochemical or non-electrochemical methods.

5 Full article: Producing a thin coloured film on stainless steels – a review. Part 1: electrochemical processes (tandfonline.com)

Thin-film interference is a common optical phenomenon seen in everyday life (see). For example, when a thin layer of oil spreads on water, a rainbow of colours appears due to the interference between light waves reflected from the top of the oil and the oil-water interface. This causes the observer to perceive colours different from the original light source (e.g. white sunlight) or the film itself (usually colourless). The effect is most pronounced when the film thickness is comparable to the light's wavelength, around 0.5 µm for visible light. In much thicker films, the interference blends into a white colour.



The principle of light interference

Rays 1 and 2 interfere

The wavelength inside the film is shorter:
l' = l / n
n = the index of refraction of the film

Ray 1 suffers a phase change of
180 degrees

Figure 2-1: Thin-film interference
Source: (Kosmac, 2011)

In a second step of the INCO process, the film is subject to a cathodic deposition in an aqueous bath of chromium trioxide to harden it to achieve an aesthetic, decorative surface with high durability when exposed to demanding conditions.

Coatings produced by the INCO process aim to achieve several key properties: enhanced resistance to scratching and marking, a wide range of stable, bright, and uniform colours, as well as good wear and UV resistance. Additionally, the process allows for combining colours and patterns on stainless steel, expanding the variety of products that can be created. According to the applicant, the INCO process offers versatility, aesthetic appeal, and durability, all at a relatively low production cost.

The Rimex process for the creation of CCS including a more detailed description of INCO process is discussed in more detail in subsection 2.5.1.

2.5.1 Description of the Rimex process of creating coloured stainless steel

Overview

The plant has partly enclosed production lines situated in bunds (**Figure 2-2**), the most recent of which, was installed in 2011. Colouring lines incorporate a number of sequential steps, including alkaline degreasing, cold-water rinsing, colouring with CrO_3 and H_2SO_4 and hardening, which are detailed in the following section. CrO_3 in solution is referred to as chromic acid (H_2CrO_4).

#B [redacted]

Figure 2-2: Colouring lines (not to scale). Source: Rimex Metals (UK) Ltd

**** Note: Black colouring solution only gives black colour.***

Chromium trioxide storage

Chromium trioxide is purchased and transported to the production plant as a flake form, in clip-top steel drums. Typically, several drums are purchased at a time, delivered on wooden pallets and wrapped in cling film. Pallets are off-loaded at the Rimex site boundary using a fork truck and taken directly to the chemicals store. The chrome flake is stored in a bunded chemical cabinet on arrival for chemical management / control.

The drums of chromic acid are kept (still on the pallet) either on the floor or on a storage bund in the chemical store.

Pre-treatment and rinsing

Pre-treatment and rinsing cleaning / degreasing of the uncoloured stainless-steel sheets is performed via an alkaline soak. In every line, the stainless-steel sheets are first immersed in the colouring tank, rinsed and then immersed in the hardener tank where electrolytic hardening takes place. Each production step is followed by one or more rinsing steps with cold water.

Tank make-up

To make the desired concentration for the lines (shown in Figure 2-2), the drums are transported using a trolley to the production line and the tank-make up is conducted.

Special prevention measures are taken at this time as the process is undertaken during the close of day when most of the workforce are no longer on site; 2-3 trained operators are provided with the adequate personal protective equipment (PPE) to perform the operation.

The transporter is driven to the load station where a titanium mesh basket is suspended from it. Special measures designed to avoid and retain any kind or releases are implemented, such as the use of PVC trays to contain spillages. The calculated number of drums are manually added to the basket. The transporter is driven to the tank and the basket is immersed in the process solution. To reduce dissolution problems, air agitation is applied to the solution.

On one of the lines an eductor mixing system is present on the colour tank in order to further reduce exposure risk to employees. An additional mechanical pump agitation takes place. Colour tanks have LEV systems with air agitation and lip extraction in place to further reduce the exposure risk to employees. Each tank is made-up in turn. Concentration of the process tanks on the three colouring lines is measured weekly by using ion-chromatography following the in-house standard operating procedures.

Stage 1 of the INCO process: colouring stage

The first stage of the INCO process is known as the colouring stage. The colouring bath is temperature-controlled, containing a CrO_3 at a set concentration and a sulphuric acid aqueous solution also with a concentration. Stainless steel sheets are immersed in this acidic bath for specific durations, during which the oxidising effect alters the surface colour of the sheets. The immersion time varies based on the thickness of the interference film needed to achieve the desired colour.

During the coloured film growth on stainless steel, a chromium-rich oxide layer forms on the surface. This oxide layer affects how light interacts with the film, resulting in the stainless steel displaying various colours. Thicker films produce darker colours .

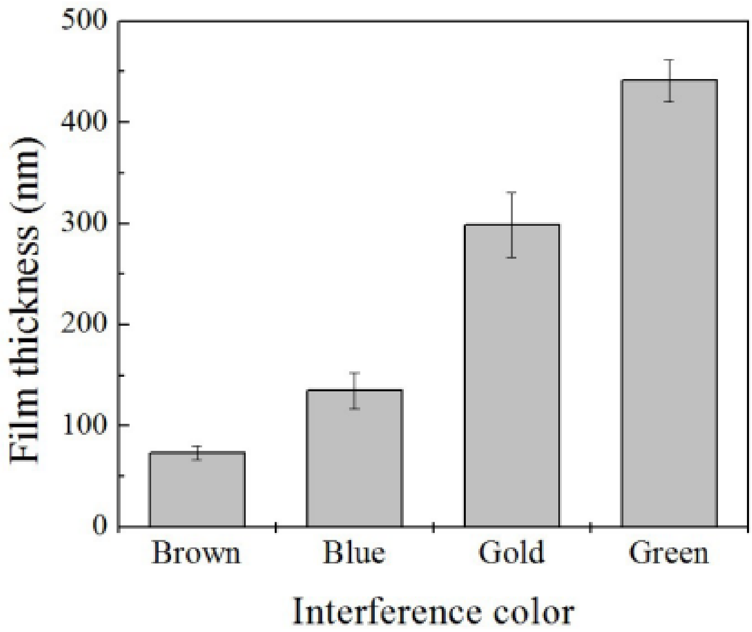


Figure 2-3: Thickness (nm) of interference coloured film measured by GDOES technique (Junqueira and de Oliveira Loureiro, 2000)[6]

The oxide layer is porous, allowing ions to migrate from the stainless-steel surface to the solution. Therefore, the colour of stainless-steel changes progressively through shades of champagne, blue, bronze, gold, rose gold, red, and green, due to a phenomenon called thin-film interference, giving the surface an iridescent quality. An example of the colours produced are shown in **Figure 2-4.**

Figure 2-4: Example colours produced using the INCO process on brushed stainless steel, from left to right, include champagne, blue, bronze, gold, and rose gold (Alliott et al., 2022)

A total of seven main colours are produced by Rimex[7]. Bronze is the first colour to appear following immersion and green is the last colour to be obtained (i.e. the colour with the longest immersion time).

Basic redox explanation

The term redox comes from the two concepts of reduction and oxidation. It can be explained in simple terms:

- Oxidation describes the loss of electrons by a molecule, atom, or ion (anodic reaction)

[6] Electrochemical coloration of stainless steel as an alternative for architectural coatings, available at: https://pdf.blucher.com.br/chemistryproceedings/s3ie/05.pdf

[7] The Rimex ColourTex® stainless steel range, available here: https://www.rimexmetals.com/products/colour-tex

- Reduction describes the gain of electrons by a molecule, atom, or ion (cathodic reaction)

The dissolution of the stainless steel into the strongly acidic and oxidising solution occurs *via* the anodic reaction in Equation (1):

$$M \rightarrow M^{n+} + ne^{-}$$

M represents ions of metals from the stainless steel. Only a small amount of the dissolved metal contributes to the formation of the film leading to an overall weight loss of the stainless steel.

The cathodic reaction involves the reduction of dichromate anions to trivalent chromium ions as shown in Equation (2):

$$Cr_2O_7^{-2} + 14H^{+} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_2O$$

To sustain the reaction and subsequent film growth, H^+ ions in the solution at the cathodic site must be continuously replenished at the rate they are consumed. The cathodic reaction takes place at the film/solution interface, starting at the stainless steel surface and progressing outward as the film develops. Metal ions from the dissolution of the stainless steel and the reduction of chromic acid both contribute to the growth of the film.

demonstrates a simplified diagram on the interference film structure and its formation during the colouring stage of the INCO process.

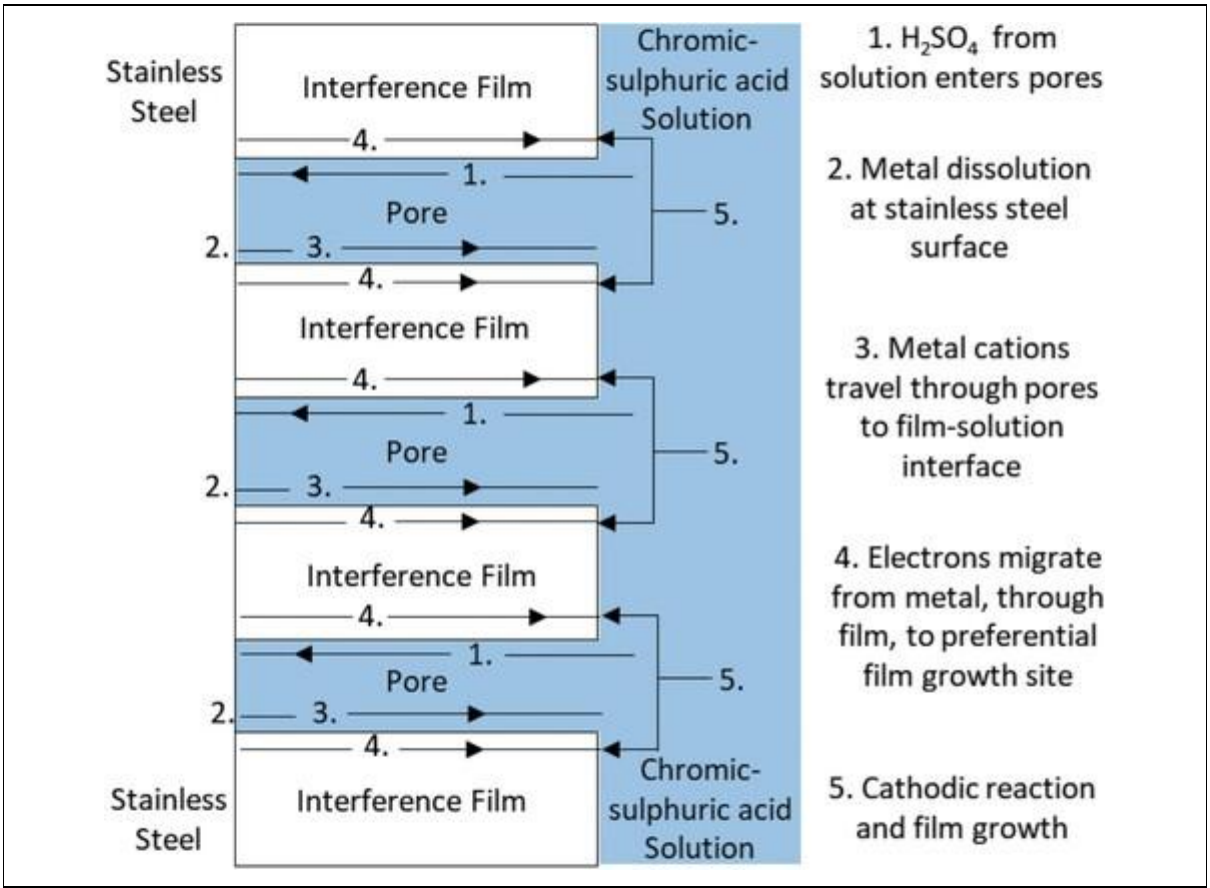


Figure 2-5: Interference film structure and its formation during the colouring stage of the INCO process (Alliott et al., 2022)

Stage 2 of the INCO process: hardening stage

The colour layer produced from this process in the previous stage is usually porous and soft and can be easily removed by hand-rubbing. The second stage, the hardening process, closes the pores in the film and increases the overall film thickness.

The stainless steel sheets coming from Stage 1 are immersed in a bath containing an aqueous solution of CrO_3 of concentration at room temperature which is submitted to a cathodic process with a low current density.

After established time has passed the already CCS sheets are rinsed and submitted to spray wash. After the INCO process is completed, no chromium (VI) remains on the surface of the stainless steel sheets.

Waste

Rinse waters contaminated by chromic acid are treated in an effluent treatment plant. In the first stage of effluent treatment, Cr^{6+} is reduced to Cr^{3+} by the addition of sodium metabisulphite ($Na_2S_2O_5$). This is controlled via an ORP probe. Cr^{3+} is subsequently precipitated out using a 45% solution of $Ca(OH)_2$ (lime), with the resultant solids separated from trade effluent using a lamella separator and filter press. The hardening solutions are tested fortnightly by tensiometer and air monitoring pursuant to COSHH and HSE regulations.

Other spent waste streams that are contaminated with Cr6+ are disposed of by a specialist contractor. These waste streams consist of:

1. Low Cr(VI) concentration waste: contaminated wipes, spill kits and PPE.
2. Old process tanks and equipment: these are partly decontaminated on site before disposal.
3. High Cr(VI) concentration waste: spent process solutions and sludge from process tanks.

Outcome of the INCO process

The interference film that is produced during the INCO process primarily consists of chromium (III) oxide, the same oxide that naturally forms on stainless steel and provides its excellent corrosion resistance. This then allows the CCS to be used in a wide range of environments.

2.6 Technical feasibility considerations from the perspective of the applicant

2.6.1 Technical characteristics of CSS manufacture

Introduction

The process for producing CCS has been in commercial use since 1973, with the first significant building featuring CSS completed in 1988. Rimex's orders for building projects increased gradually throughout the 1990s, becoming more consistent in the 2000s.

CCS produced by Rimex using the INCO process has featured in several high-profile building designs, this also includes buildings of significant cultural heritage. One of the most well-known buildings featuring INCO CSS produced by Rimex is the Wales Millennium Centre in Cardiff, see **Figure 2-6**.

Figure 2-6: Wales Millennium Centre in Cardiff featuring

Located in Cardiff Bay, the iconic building and symbol of Wales uses three different ColourTex® range of products, the products as part of the exterior design and the bronze theme is carried through to the interior of the building. Additional examples of Rimex's British made INCO CSS are included in Annex 2.

The output for CSS has fallen slightly since 2020 following a slowdown in customer demand during and post-COVID. During and post-COVID attributable factors this reduced demand include a decline in construction activity across Europe. There has been a rise in the popularity of PVD-CCS (an alternative to CSS) in both European and UK markets, while increasing consumer prices, increasing energy costs have been factors that have contributed to a downturn and stagnation in the European and UK stainless steel markets since early 2023.

INCO CSS has proven durable and reliable over time, with the Rimex CSS range earning the attention of renowned architects and becoming more widely specified and used than it was 5, 10, or 20 years ago. Improvements in production processes and efficiencies have also been implemented, contributing to this growth.

In response to industrial emissions regulations, including the Integrated Pollution Prevention and Control (IPPC) directive (Official Journal of the European Union, 2010), Rimex made significant changes in 2008 to meet the requirements set by Thames Water and the Environment Agency. These changes not only improved environmental safeguards but also enhanced production efficiency.

In addition to these past improvements made to the site, Rimex are part of the UK Best Available Techniques (UK BAT) Technical Working Group (TWG) that are currently reviewing and in the process of updating the UK BAT for the Surface Treatment of Metals and Plastics (STM). The UK BAT TWG is supporting the updating UK BAT for STM which in addition to considering BAT for reducing emissions to air and water, the process will also consider BAT for energy efficiency, materials efficiency, noise management, waste prevention and reduction.

2.6.2 Technical characteristics of CrO_3 in the process of CSS manufacture

Chromium trioxide performs two tasks in the colouring process.

Stage 1: It acts as an oxidising agent by forming a thin, porous oxide film on the surface of the stainless steel, which acts as an interference layer.

Critical parameters of stage 1:

- Concentration
- Purity
- Temperature
- Pressure
- Time reaction

The process performed is easy to maintain and reproduce the same quality CSS. The purity of the starting materials is high; this helps to prevent unwanted secondary reactions that may affect the quality of the final product or spoil the bath solution. The temperature is easy to maintain, and the energy required in the process to maintain the temperature allows a balance of positive income. Maintain a stable pressure as part of the process is important. The reaction time varies by colour, but the times are generally quite short which helps Rimex to produce CSS efficiently and profitable.

On the contrary, significant lower temperatures and concentrations lead to unacceptably long process times. The solutions are relatively robust with respect to build-up of impurities (e.g. Cr(III), Ni and Fe salts). Sludge builds up at the bottom of the tanks over the time and eventually, after 3-6 years, the sludge layer will build up to a level that the sheets being processed begin to make contact with the sludge which affects quality. At this time the solution is replaced, and the sludge is removed from the tank.

Stage 2*:* In the cathodic hardening stage, chromium trioxide deposits in the voids within the porous interference layer, making it physically robust.

Critical parameters of stage 2:

- Room temperature
- Pressure
- Low current density
- Bright
- Hardening (Vickers)
- Reproducibility
- Time reaction

Higher current density will cause chromium to plate out. Sulphuric acid builds up through drag out and is generally present in at low level (e.g. 40 g/L) without affecting performance.

Critical parameters of the process:

- The lines run the full width of the factory floor. It would not be possible to accommodate tanks for additional process stages. Therefore, any alternative should use the existing lines
- Any alternative that involves using oxidising agents should be tested in order to avoid any violent or undesired reactions as this would impact worker safety

- Process time is important
- Service life of process solutions is important
- Production rate

Critical parameters of the final products:

- Similar (not necessarily identical) range of coloured products
- Durability (corrosion)
- Stability (wear, resistance)
- Ductility and welding
- Generation of off-specifications products
- Regulation requirements (standards, emissions, etc.)

As chromium trioxide is a primarily constituent of both stages oxidation and hardening, in the instance when two different solutions (i.e. solutions with different constituents for each stage) would be used as alternative, care should be taken so that the constituents (and required conditions) of the colouring solution do not create problems downstream, to the hardening process. Otherwise, an intermediate process step will have to be introduced (e.g. rinsing, neutralisation) increasing the process cost and complexity.

Whether a different colouring solution or an entirely different production technology, modifications will be required in many auxiliary aspects of the production process.

- Oxidising agents are generally highly reactive substances and may undergo violent reactions if the conditions are not properly controlled. A different oxidising agent would require strenuous testing to minimise this danger. In that case, the operational conditions will be different than the current ones which would potentially require new risk management measures and intensive training of the personnel.
- The service life for process solution is also an important factor for Rimex, since it affects the cost for raw materials and also the need for concentration adjustment procedures. The latter may also affect the number of incidents/accidents (e.g. a higher frequency of concentration adjustments may result in a respectively higher frequency of spills or other incidents).
- Chromium mist generation is a potential cause of exposure to hexavalent chromium (Barnstead & Bieler, 2009). It is currently controlled through the use of a mist suppressant and extraction (ventilation). This is more intense during the hotter colouring stage. If the alternative can reduce (eliminate) the potential chromium (VI) mist generation and thus reduce the potential exposure of the workers to hazardous chemicals, it will then provide an additional benefit (social and economic).

Production plant flexibility

As it has been shown in **Figure 2-2**, the current production lines for producing CSS are a quasi-continuous process. The manufactured CSS is based on metric standards, but different sized sheets are processed depending on customer requirements. The maximum dimensions of sheets that can be process are 4,000 mm x 1,250 mm although Rimex also process many special sized parts, include small components for the automobile industry (e.g. car grills).

The capacity of tanks and the duration solutions are present within them is an important parameter due to the volume and reactants used in the tanks, colouring and hardening solutions can last until 10 years, whereas blacking solution last approximately 2 years.

Therefore, when assessing potential alternative solutions or technologies, the following points should be taken into account:

- The need for additional process steps (e.g. an intermediate rinsing or neutralisation step between colouring and hardening)
- The product units that are handled by this alternative technology (i.e. sheets, coils or other forms)
- Durability of the solution for colouring, hardening, blackening separately of alone if it one step process

3 Analysis for Alternatives

3.1 Introduction

The technical feasibility criteria were initially described in more extensive detail as part of the initial application. However, this application was originally submitted to ECHA when the UK was a member of the EU, this AoA section contains an overview of previously submitted information and a focus on developments since Rimex's initial application was granted and then later grandfathered.

Rimex have committed to a total of two PhD studies looking into alternatives, the most recent of these PhD studies was finished during the recent review period, both studies found that the possible alternatives were not viable.

3.2 SVHC use applied for

The use applied for is to use chromium trioxide as an oxidising and hardening agent in the manufacture of CSS for use in the following sectors/industries:

- Architectural
- Engineering
- Machinery
- Refrigeration
- Elevator
- Transit

3.2.1 Description of the function of the Annex XIV substance and performance requirements of associated products

The technical feasibility and associated performance requirements are described in detail in Section 3.3 and build on the factors previously described in Section 2.

3.2.2 Market analysis of products manufactured with the Annex XIV substance.

Rimex are a downstream user of chromium trioxide and produce CSS that meets the specific colour demands of their customers. As indicated above, these CSS are products for several different sectors.

Within these sectoral supply chains, Rimex are a contract manufacturing company, where clients strategic outsource or form a partnership with Rimex who are hired as a specialised manufacturer to produce CSS according to specific colour demands. This model is also typically referred to as a "build-to-print" or subcontracting relationship.

The relationship allows Rimex's customers to achieve their specific requirements and it allow the client company to focus on designing, marketing, and sales while leveraging the expertise, track record, specialism and existing equipment (and therefore cost savings) that Rimex are able to offer.

As Rimex are a contract manufacturing company, who produce CSS for uses in several sectors, they are not the original designer of the components or the company that sales the end products directly to market.

Although Rimex are responsible for the safety of their workforce when using chromium trioxide at the site, they are not the company in the supply chain that are responsible for ensuring that other regulatory requirements, legal requirements and other national/international standards on technical performance or certification requirements are being meet.

In the example of architectural use of CSS, it will be role of other companies in the supply chain to ensure that key technical requirements for the use of CSS in the construction sector are being meet. This will include specific industry standards for fire rating. Although stainless steel building products do not possess an intrinsic fire rating as a raw material, it should be noted that they are widely used in fire-rated construction because they are non-combustible, do not propagate fire, and retain structural strength better than other materials at high temperatures. However, the regulatory requirements focus on the performance of the finished assembly rather than the material itself[8].

The INCO CSS process adds a very thin coating to the steel, so while it helps to protect the surface, it does not significantly increase the structural strength of steel.

Rimex are the only INCO CSS company that appears to operate within the UK. Rimex have at least two INCO CSS competitors in the EU. One of these companies has been in a form of administration and it is possible that it will close and its capacity for INCO CSS will become available.

It is unclear to Rimex whether the other company have an active REACH Authorisation that covers their chromium trioxide uses as part of the INCO CSS process. They are not an applicant for their own Authorisation so they would otherwise need to be covered by an upstream application. In the future the competitors use of chromium trioxide is expected to be fall under the obligations of the ongoing Chromates EU REACH Restriction.

There are many companies in the EU and a handful in the UK that offer sheet PVD CSS. These tend be metal distributor companies that offer all stainless steel products irrespective of whether they actually sell them.

Based on Rimex's knowledge of PVD CSS, which is described in subsequent sections, the PVD CSS that is placed on the UK (and EU) market originates from Asia because it is cheaper to manufacture and import PVD CSS from Asia than it is to manufacture PVD CSS in the UK due to higher energy and labour costs. Where competitors may state they manufacture PVD CSS, it is expected that this is either not strictly true or where companies may actual be manufacturing it, the plant may be supported with PVD imports from Asia.

Other regulatory requirements and barriers exist but these are not REACH Regulation related barriers, these include the Carbon Border Adjustment Mechanism (CBAM)[9].

3.2.3 Annual volume of the SVHC used

The typical annual volume of Rimex's chromium trioxide product use is:

- #A tonnes (2 - 9 tonne) CT/year

[8] Fire safety concerns of building materials include INCO CSS have not been assessed within this application, other stakeholders in the supply chain will need to ensure regulatory compliance with relevant regulations, certifications and safety requirements

[9] Carbon Border Adjustment Mechanism (CBAM), the EU's environmental policy tool for carbon emissions pricing, available here: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

The annual average tonnages used by Rimex has been in this range for the past several years. This trend is expected to continue for the next several years. The annual volume of chromium trioxide consumption is provided in **Table 3-1**.

Table 3-1: Overview of chromium trioxide consumption in UK

Year	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026-32 (estimate)
Chromium trioxide volume (tonnes)	[redacted] #A									
This tables shows that Rimex have consistently used between 2-9 tonnes of chromium trioxide for the past several years. *Predicted level of 2025										

As indicated in the table, [redacted] #C, D [redacted]

The annual volume may increase if the global economy grows leading to greater demand for construction projects and other products contain CCS. If EU competitors leave the market this may also lead to an increased demand for Rimex's CSS.

3.2.4 History of chromium trioxide use by Rimex

The colouring of stainless steel consequent to immersion in a solution containing chromic and sulphuric acid has been known for over 80 years, however, the fragility of the coloured film did not allow for immediate commercial application. In the early 1970s, INCO conducted research on a process to "strengthen" this thin film and produce a marketable CSS product. This technique, modified by further internal R&D activities, resulted in a number of patents and has been commercially used for over 40 years now.

Rimex acquired a licence to CSS from International Nickel Co Ltd, from its European research development centre in Birmingham, in 1973. That same year a pilot plant was set up and subsequently took the CSS product to a commercial scale, where it has operated since. The plant expanded in 1974 and was relocated to Enfield, London. It relocated again in 1995 to its current location (still in Enfield), after it was upgraded. A third colouring line was installed in 2011 in order to meet customer demand, to standards agreed with the Environment Agency under the Integrated Pollution Prevention and Control (IPPC) regime.

Prior to this, in 2008/2009 the on-site effluent plant that links to the manufacture of CSS was substantially upgraded, including being fully bunded internally and externally, pursuant to directions of the Environment Agency under the IPPC. Renovation works to Lines 2 and 1 were undertaken in 2012 and 2015 respectively. Work on Line 2 included separating a bund that linked Lines 1 and 2, in order to give both lines their own sump. Throughout this period, CrO_3 was the chemical of choice, along with sulphuric acid, the reason being that it was prescribed in the patent, and it had shown high quality results.

Rimex is the only UK manufacturer of INCO CSS while there are two other companies in Europe that manufactures CSS using the INCO process. There is one manufacturer in the USA and another in Japan and it is thought that there might be manufacturers in China, but these are not well known to Rimex.

3.2.5 Overview of key functions

As noted in section 2, stainless steel is widely used in architectural design, particularly for decorative functions.

The INCO process is a two-stage electrolytic method that produces a range of colours on stainless steel surfaces, primarily for decorative, architectural, and aesthetic applications, while preserving the metal's inherent corrosion resistance. Chromium trioxide (EC: 215-607-8, CAS: 1333-82-0) is important to the process.

The first stage of this process involves immersing stainless steel in a heated acidic electrolyte, comprising CrO_3 and H_2SO_4 at approximately 70 °C. In this process, CrO_3, a powerful oxidiser, works with sulphuric acid to form a thin film of chromium(III) oxide ($Cr2O_3$) on the stainless steel surface, imparting colour through thin film interference.

Following this initial stage, the coloured film undergoes cathodic treatment in another acidic solution containing CrO_3, effectively 'hardening' the film. An electric current is applied during this stage, resulting in the formation of a transparent oxide layer on the steel's surface, with the stainless steel acting as the cathode.

The colour produced is determined by the thickness of this oxide layer, which can range from nanometres to microns. This layer generates colours through light interference effects—similar to those observed in oil films or soap bubbles—without the use of pigments or dyes. Variations in thickness alter the way light reflects and refracts, producing a spectrum of colours.

The INCO process is a popular choice for creating CCS due to its ability to deliver a durable and aesthetically pleasing finish without compromising the material’s performance.

3.3 Technical feasibility criteria for the role of CrO_3 in the applied for use

3.3.1 Introduction

The analysis of the technical feasibility of alternatives for CSS without using chromium (VI) must consider whether the functions performed by this substance can be achieved through another substance or technology. Therefore, it is essential to examine the role of chromium trioxide in the two-stage process and assess whether these stages can be consolidated into a single process while still meeting the final product's quality standards.

Additionally, when selecting an alternative substance or technology, it is important to consider the specific requirements of downstream users regarding the characteristics of CCS.

Choosing an alternative for producing durable colour in stainless steel requires balancing various factors such as qualities, properties, and technical parameters. Alternatives identified in this analysis fall into two main categories:

1. Alternative substances, which can directly replace chromium trioxide (CrO_3) in the colouring (and, if necessary, hardening) stages with minimal or no changes to production lines. These alternatives follow similar principles to the INCO process, where the stainless steel is coloured oxidatively, and the colour layer (film) may be hardened through a chemical or electrochemical reaction. However, in practice, such alternatives are likely to be suitable for either colouring or hardening, but not both. Achieving the same quality as current products may require additional processing. As discussed in Section 4, most identified alternatives can

colour stainless steel sheets, but no studies or patents have confirmed their effectiveness in the hardening stage.

2. Alternative technologies, which utilise different principles from the current process, producing colour on stainless steel through distinct mechanisms. These methods do not directly align with the steps of the INCO process and would likely require completely different equipment and techniques.

Considering both categories of alternatives, the technical feasibility criteria relevant to the production of CSS, including their respective thresholds or acceptable performance levels, where available each are listed in **Table 3-2**.

Table 3-2: Summary of technical feasibility criteria

#	Criterion	Relevance		Threshold
		Process	Product Specification	
1	Colour quality		✓	Not quantifiable. It should be free of visible defects such as staining, marks, spotting etc. Requirements: brightness, uniformity, overall appearance and as low as possible generation of off-spec products
2	Product range		✓	Should include all INCO colours, patterns and substrates (1.4301 and 1.4401 steel grades)
3	Durability		✓	Resistance to UV radiation and salt spray testing Self-healing is considered an added bonus
4	Process temperature	✓		Below existing process temperatures < #B, D (below 100 °C)
5	Process duration	✓		The process should be efficient ≥ #B, D sheets per day per line
6	Use of existing equipment	✓		Not quantifiable. Existing factory floor space/ equipment must be used to the degree possible
7	Energy consumption	✓		Equal to or below levels of energy consumption < #B, D kWh/m2 (<1 kWh/m2)

There are other critical factors that have not been included in the table but would also be considered when consider the suitability of alternatives, these include if the alternative is likely to be a regrettable substitution and the cost & availability of the alternative substance(s).

The criteria presented in **Table 3-2** helps determine the feasibility of alternative approaches and may relate to both process parameters and specifications of the final CSS product. A detailed discussion of these criteria follows is presented in section 3.3.2.

Rimex's extensive experience with oxidising reactions highlights their sensitivity to operating conditions, such as temperature, pH, and the presence of impurities like metal ions, which can catalyse reactions, leading to excessive heat generation and unwanted decomposition. The size of the process tanks is also a critical factor, particularly in the colouring and hardening stages.

3.3.2 Discussion of technical feasibility criteria

Criterion 1: Colour quality

Importance of the criterion

The defining characteristic of CSS is its colour, which imparts a distinctive appearance in various applications, including construction projects, manufacturing, lift doors and cabins, and shop fittings. The colour of CSS can be easily identified by its associated light wavelength or by using common colour scales such as RGB or CMYK.

Experience indicates that the high lustre and brightness of CSS products are key factors in their commercial success, especially in high-end applications where these properties are highly valued. Uniformity of colour is also crucial, particularly in architectural applications. While the INCO process generally produces uniform-coloured films across the metal surface, variations can occur between different sheets and batches of stainless steel. Significant inconsistency in product quality, however, has to be managed and makes project management crucial. To mitigate this, an acceptable colour range is often agreed upon with the customer in advance.

CSS products that do not meet acceptable quality standards are typically rejected either on the supplier or internally. While some of these rejected sheets may be successfully reworked or accepted as rejected by the supplier, the majority are scrapped. A high rejection rate leads to increased costs per unit, as more raw materials, utilities, and other resources (including time and labour) are needed to replace the unacceptable batches. This, in turn, reduces the production capacity of the plant.

Threshold

Determining whether the colour quality and uniformity of CSS are suitable for a given application is managed to production parameters. Despite best efforts to determine it, it is challenging to establish uniform, quantified criteria for what constitutes the "best" CSS.

However, the volume of unacceptable CSS produced due to poor quality or inconsistent colour can serve as a useful indicator of an alternative's performance. Currently, CSS products failing to meet specifications represent a low quantity of Rimex’s total CSS production. Any technically feasible alternative would need to demonstrate similar or lower rejection rates.

Criterion 2: Product range

Importance of the criterion

One of the main advantages of the INCO process for CSS production is the variety of the products that can be produced by it. By variety it is typically meant the range of colours that may be produced that can be combined with other finishes such as patterns, polishes, bead blast. Rimex currently produces the following colours: black, blue, bronze, champagne, gold and rose gold. The process allows for the production of colour-patterned, bead-blasted, polished, and various other finished sheets, creating an extensive product range. These colours are available in “bead blast,” “mirror,” and “satin” finishes, as well as patterned substrates, on stainless steel grades 1.4301 and 1.4401. The combination of colours and patterns on stainless steel results in a wide variety of products tailored to different applications.

This variety is particularly appealing to Rimex’s customers in the architectural and lift sectors, where functionality, design, and aesthetics are highly valued. Given the specific needs of these customers, the removal of a particular colour from the product range does not necessarily boost the sales of other colours. For example, if an architect envisions a rose gold façade for a building, they will specifically seek out rose-coloured materials. If rose gold CSS is unavailable, the architect is unlikely to select a blue CSS, regardless of the material's overall quality.

Threshold

Ideally, an alternative would be able to provide at least a close or similar range of products. An alternative would be considered acceptable if it could produce at least the most important colours in terms of sales.

Criterion 3: Durability

Importance of the criterion

Any CSS produced using an alternative process must be visually appealing and consistent in both quality and colour to meet Rimex's customer requirements. Equally important, it must be durable enough to withstand the demands of fabrication and environmental exposure and not rub away or discolour.

CSS is commonly used in applications with long lifespans, particularly in the architectural sector, where it may be used on the exteriors of buildings or other structures. Building cladding, for instance, is expected to last between 10 to 40 years or more, while lifts and escalators typically remain in service for around 15 years. This highlights the need for durable materials in these applications.

When CSS sheets are exposed to atmospheric conditions, they must demonstrate good corrosion and whether resistance. INCO CSS has been tested for corrosion resistance through UV and salt spray testing, with results showing satisfactory performance. While the thin coloured layer on the stainless steel may slightly enhance the corrosion resistance of the substrate, this effect is not considered critical. Therefore, the primary concern regarding durability is the longevity of the aesthetics, provided that the alternative process does not negatively impact the substrate's inherent anti-corrosion properties.

Threshold

The lifespan of CSS should be the same as that of plain stainless steel, as long as it is looked after and maintained. Alternatives should be able to produce colour that can last at least as long as INCO CSS. This is a difficult criterion to evaluate. This is mostly achieved by visual inspection of CSS already on buildings in the field and through simulated testing (especially UV testing).

Criterion 4: Process temperature

Importance of the criterion

The process temperature is a critical parameter in CSS manufacturing, as it significantly influences both the reaction rate and the quality of the final product. Colouring of stainless steel appears to happen spontaneously at the temperature used in the colouring step of the INCO process, thus removing the need for additional chemical or electrochemical aids. Higher temperatures may lead to a non-uniformly coloured sheet. At present, colouring takes place at elevated temperatures (i.e. 70-100 °C).

Higher temperatures need more energy to maintain, thus increasing process costs. Additionally, all colours in the INCO process can be produced at the same temperature, so there is no need for changes between different batches. This reduces idle time, increasing productivity.

Finally, the temperature of the solutions affects the generation of fumes or vapours. As such, higher temperatures would require stricter and more expensive risk management measures (e.g. more intensive ventilation).

Threshold

An alternative should be able to perform near the current temperatures or as close to room/ambient conditions as possible to reduce risks and energy costs. If higher temperatures need to be used, they should be accompanied by increased productivity.

Criterion 5: Process duration

Importance of the criterion

The production time required for each finished sheet of CSS is a crucial process parameter, as it directly determines the plant's capacity. Rimex processes stainless steel sheets sequentially, with no two sheets ever in the same tank simultaneously. This means that each sheet must wait until the processing of the previous one is complete. As a result, the number of sheets (of a given size) that can be processed daily is fixed and limited by the specific requirements of each colour.

Longer processing times reduce production capacity, thereby proportionally limiting potential turnover from CSS sales. Conversely, significantly shortened production times may lead to challenges in maintaining process control. Overall, production time not only affects capacity but also impacts lead times to customers, making it a key factor in production planning.

Threshold

In Rimex's plant the time required for the manufacture of a sheet of CSS ranges between a few minutes and several minutes based on the desired colour profile, in addition to the colouring process time is also needed for the hardening process. Based on Rimex's existing knowledge of their maximum production rate, in order to maintain (if not increase) the current plant's capacity, technically feasible alternatives should be able to achieve at least the same level of throughput.

Criterion 6: Process temperature

Importance of the criterion

Rimex have made significant investments in the manufacturing plant over the past decade. Installation activities that took place in 2011 and now likely to be approximately three to four times the cost.

In case an alternative requires different equipment, these costs will be sunk and Rimex will not be able to recover or depreciate them. As Rimex is an SME, the availability of capital for investments can be limited.

These lines typically have a lifetime of at least 25 years. However, the durability of the older lines suggests that in reality, lifetime usually exceeds this.

In addition, it is important to note that the existing lines run the full width of the factory. It would not be possible to extend them to accommodate tanks for additional process stages, so any alternative process (using the same production lines) would have to be feasible with the same or fewer treatment tanks.

Finally, an alternative should ideally be able to colour sheets of the same size as the current production lines. The maximum dimensions of the sheets are 4,000 mm x 1,250 mm, while standard sized sheets are usually 2,500 mm x 1,250 mm or 3,000 x 1,250 mm. Other special sized parts, such as small components for the automotive industry, are also processed under the INCO CSS process.

Threshold

There is no quantitative benchmark for this criterion; however, alternatives can be characterised based on the level of modification required as follows:

- **No change or minor operational modifications:** The alternative could directly replace CrO_3 with minimal adjustments, such as slight changes to operational conditions like process temperature.
- **Use of existing lines with modified conditions and minor equipment adjustments:** The alternative could utilise some existing equipment for CSS production, implying a solution-based approach. This would require modifications that may be relatively straightforward and could be implemented with a reasonable investment, potentially involving the same or fewer tanks.
- **Use of entirely new equipment for colouring and hardening:** This scenario would require completely different machinery that cannot be accommodated by the current setup. Additional space might be needed, increasing costs due to the need for extra land or leasing. Flexibility may exist if the alternative process can colour sheets of the same size as those produced by the INCO CSS process (refer to dimensions above).

In reality any option other than no or minor operational changes to the lines has the potential to significantly impact Rimex's ability to operate. Regarding waste treatment, it is important that any waste generated by a new process using an alternative substance or technology does not necessitate the construction of a new waste treatment unit on-site. However, it is likely that any viable alternatives would require a completely different setup, including a new effluent treatment system. Therefore, this criterion will primarily be considered as indicative.

Criterion 7: Energy consumption

Importance of the criterion

Energy consumption, which consists of approximately 50% electricity and the remainder from purchased fuels (primarily natural gas), constitutes a modest portion of the overall production cost for CSS. Significant increases in energy consumption have the potential to impact the facility's profitability. It is worth noting that CSS is less energy-intensive compared to other types of electroplating in terms of overall electricity use.

The UK's higher electrical energy costs for businesses, compared with those in the EU, are a potential barrier for moving from INCO CSS to the higher energy PVD CSS (which has other feasibility challenges). The UK Department for Energy Security & Net Zero (DESNZ) own Energy Prices International Comparisons[10] suggest that electrical energy cost in the UK from 2020-2023 are on average around 52.7% higher relative to the EU 27.

[10] DESNZ International industrial energy prices, available at: https://www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices

Threshold

The cost of energy consumption should not rise to a degree that it affects the profitability of the plant. In 2024, total energy consumption per m^2 of CSS produced (#B, D m^2) was #B, D kWh of gas and #B, D kWh of electricity.

3.3.3 Summary of conditions and parameters of chromium trioxide use

Table 3-3 summarises the functionality of CrO_3 in the applied for use and presents the parameters of use that are of importance to assessing the feasibility of alternatives.

<table>
<tr><th colspan="2">Table 3-3: Key parameters of use of chromium trioxide</th></tr>
<tr><th>Parameter of use</th><th>Conc. (%)</th></tr>
<tr><td>Task(s) performed by the substance</td><td>Acts as oxidiser for the formation of a thin light interference layer on the surface of stainless steel (colouring → appearance enhancement). Facilitates the deposition of metal ions on the thin, porous layer making it physically robust (hardening → durability enhancement during fabrication and use)</td></tr>
<tr><td>Physical form of the product</td><td>Solid (flakes); added to tanks to create solutions. Chromium trioxide is used in two stages of the process: colouring and hardening. The CrO_3 in the solutions is slowly consumed and it is replenished periodically by direct addition of CrO_3 flakes in the tanks
Colouring stage: chromic acid in sulphuric acid (range: 100- 1,000 g/L for both) at elevated temperature (range: 70-100 °C)
Hardening stage: chromic acid (range: 100-1,000 g/L) in water at a temperature lower than the colouring stage
Blacking: chromic acid and H_2SO_4 (range: 100-1,000 g/L for both) at elevated temperature (range: 70-100 °C)</td></tr>
<tr><td>Critical properties and quality criteria CrO_3 must fulfil</td><td><table>
<tr><th>Criterion</th><th>Importance</th><th>Threshold</th></tr>
<tr><td>Colour quality</td><td>Ensures the reputation of Rimex in producing high quality CSS</td><td>Not quantified. Need to meet customers’ requirements</td></tr>
<tr><td>Product range</td><td>Narrow product range may lead to loss of market share</td><td>At least the four highest selling colours out of the current selection</td></tr>
<tr><td>Durability</td><td>Ensures long life of products and increases confidence of clients in the product and Rimex</td><td>Should last as long as current CSS products and have similar resistance to external conditions (proven lifetime this far: 35 years and counting)</td></tr>
</table></td></tr>
<tr><td>Function conditions (frequency of use and quantity used)</td><td>Concentration of the process tanks on the three colouring lines is measured approximately weekly by in-house ion chromatography and the required CrO_3 is added</td></tr>
<tr><td>Process and performance constraints concerning the use of the substance</td><td><table>
<tr><th>Criterion</th><th>Importance</th><th>Threshold</th></tr>
<tr><td>Process temperature</td><td>Temperature affects colour uniformity, production costs and worker exposure</td><td>Below existing process temperatures (below 100 °C)</td></tr>
<tr><td>Process duration</td><td>Affects production throughput. May influence product quality, as shorter times are more difficult to control</td><td>The process should be efficient and produce a similar sheets per day per line</td></tr>
<tr><td>Use of existing equipment</td><td>Recent capital investments would not be lost. Reduces impacts from downtime for switch to alternative and need for additional investment from an SME</td><td>No or minimal changes to plant layout (with required operational condition changes)</td></tr>
<tr><td>Energy consumption</td><td>Significant increase in energy use could affect overall profitability</td><td>Equal to or below levels of energy consumption (<1 kWh/m2)</td></tr>
</table></td></tr>
</table>

Table 3-3: Key parameters of use of chromium trioxide	
Parameter of use	**Conc. (%)**
Conditions under which the use of the substance could be eliminated	The removal of CrO_3 from the production process of CSS would completely stop its production at Rimex's plant. The substance needs to be replaced by another oxidiser that could perform the colouring and/or the hardening of the coloured film. Alternatively, the INCO colouring process would need to be replaced with an alternative technology that could generate CSS without Cr6+. Replacement with another oxidiser will probably not require modifications to the layout of the plant but could affect process parameters such as time and temperature. Use of a different production technique would require major modification of the production layout
Customer requirements associated with the use of the substance	There are no requirements from downstream users regarding the use of CrO_3, but they have shown strong preference to the product of the INCO process because the INCO CSS product is well established after ca. 40 years of sales and promotion. Certain customers have built product lines around INCO CSS. The customers require a high-quality range of CSS possessing excellent stability and durability properties that will allow them to implement their creative plans
Industry sector and legal requirements for technical acceptability that must be met, and the function must deliver	The effect of using CrO_3 for the production of CSS is mainly aesthetic, although it does provide some additional corrosion resistance, which is already high in the stainless steel. Any legal requirements for technical acceptability must be already fulfilled by the stainless steel used as substrate.

3.4 Shortlisted alternatives from the parent application

Potential alternatives to Cr(VI) in CSS are shown in **Table 3-4**. This list comprises of the alternatives that were reported in the parent AfA as being realistic or the most promising but unrealistic in at least the short-, medium- and potentially the long-term. These alternatives include both alternative substances and alternative technologies.

Table 3-4: Promising alternatives reported in the parent AfA		
Alternative	**Feasibility**	**Future potential use**
PVD (Physical Vapor Deposition) CSS process	Could be used to create CSS however cannot yield products corresponding to the applicant's performance standards concerning colour range, UV/wear resistance, aesthetics, lifetime behaviour and process parameters such as the restriction to the size of the sheets due to requirement of use a vacuum chamber.	Only realistic alternative
Sulphuric Acid	Could be used in an electrochemical colouring process alternative to INCO process. From the vast literature the applicant concludes that much more investigation work should be done in terms of film properties and more given proof on an industrial scale.	Possible alternative
Thermal hardening	This technology cannot produce coloured films by itself, so there is always a need for a colouring step, but it could be used to harden coloured films obtained through an electrochemical process.	Possible alternative
KOH	The patent and the literature point out some potential, but it is not proven at industrial scale. Process temperatures and colour range are promising, process parameters seem to be similar to INCO process.	Possible alternative

Table 3-4: Promising alternatives reported in the parent AfA		
Alternative	**Feasibility**	**Future potential use**
Transition Metal Compounds	This substance is a possible candidate to substitute the CrO_3 in the INCO CSS process. It has potential to produce interference colours like CrO_3 films, and so it is expected that the same range of colours can be achieved, but any given proof on an industrial scale is unknown. It is also not known if it could be used to coat the type of stainless steel used by Rimex as substrate, because there is a lack of experimental data to characterise the film properties.	Possible alternative

3.5 Efforts made to identify alternatives

3.5.1 Research and development by Rimex

Rimex has been using CrO_3 to produce CSS for over 40 years, with very good results in terms of the quality of the final product. As such, prior to the listing of CrO_3 in Annex XIV of REACH, there was no requirement to undertake R&D to identify alternatives to CrO_3; the current process was developed after strenuous testing and R&D activities and the Cr^{6+} substance has been used with due care with regard to worker exposure and environmental releases.

Since 2013, Rimex have sponsored two PhD's at to investigate alternatives to using CrO_3. The first PhD focused on 'The Electrochemical Colouring of Austenitic Stainless Steel in Chromic Acid Free Solutions' with second PhD building on the results of the initial PhD and looking at other possible solutions.

Both PhD studies include data searches being performed and the identification of alternatives which were taken forward for testing. The results of the PhDs ae explored in sections 3.5.1.1 to 3.5.1.3. The most relevant sections of the second PhD focusing on the testing of alternatives are included as part of a separate Appendix (Appendix 1).

As part of the initial PhD, it was identified that there is little stated in the literature about chromic acid free alternatives. Initially identified potential alternatives for further consideration were identified as part of the original PhD and a literature review as part of the initial application identified additional alternatives, these alternative substances and technologies were described and assessed in the original application and an overview of the screening is included in Annex 3. Rare earth metals were also considered as a potential candidate, but these were excluded from further considerations based on economic feasibility.

The main focus of the PhD were on finding technical feasible alternatives but as shown Annex 3 other factors include economic feasibility and safety were also considered.

3.5.1.1 The Electrochemical Colouring of Austenitic Stainless Steel in Chromic Acid Free Solutions – initial PhD

The first PhD sponsored by Rimex was undertaken from October 2013 to October 2016 and focused on the following objectives:

- To examine suitable alternative oxidising media to colour stainless steels
- To develop a suitable alternative colouring process route that does not involve the use of chromium trioxide, or any other material under regulatory threat.

As part of the PhD study several possible alternative substances were considered. Based on the literature some alternatives were taken forward for testing. A summary of the alternative processes investigated for CSS without chromic acid are shown in **Table 3-5**.

Table 3-5: Alternative processes investigated for CSS without chromic acid	
Alternative colouring methods	**Results**
Alternative A	• Testing on this method was unsuccessful • Only unattractive coloured samples could be produced
Alternative B	• Initial testing did not offer promising results • Only blue coloured samples could be produced • Not very adherent

Alternative A

As indicated in the table the testing and the original application, testing with this possible alternative was unsuccessful and it did not produce the desired range of colours.

Alternative B

Rimex's funded PhD student conducted further testing using substance solutions at a pH of 1 (adjusted with hydrochloric acid), which yielded promising results. The solution helped to produce:

- Wide variety of coloured films can be produced
- Process can be done as an immersion process
- Short treatment times (up to around 20 minutes at room temperature)
- Can be performed at room temperature
- Samples do not require pre-treatments, i.e. washing to remove grease is all that is required
- To create a black film, immersing the sample for 5 minutes in a solution at 40°C results in a flaky black layer on the surface. This indicates that all possible coloured films have formed, culminating in the final black flaky film.

This testing of the solution has shown that a wide variety of coloured films can be produced on stainless steel using an acidic solution. This process occurs quickly, and at room temperature. However, several drawbacks were noted from this alternative process, these are highlighted below.

1. **Coloured film is not uniform**
   - The initial testing used samples that are small, which were not necessarily be representative of how the process would occur on a larger industrial scale
   - On larger samples the non-uniformity in colour may not be as noticeable

2. **Whilst wet the adhesion of the film is poor**
   - Some of the discolouration on the samples occurred from water remaining on the surface during drying of the sample
   - If a water droplet remains on the sample, significant discolouration occurs to the area underneath the water droplet
   - When all the deionised water is quickly removed from the sample surface, the sample does not exhibit the same amount of discolouration
   - Once dried, the films are not as easily damaged, although a hardening stage may be required.

Further testing of the solution was undertaken. Results of this are summarised in **Table 3-6**.

Table 3-6: Further testing of the solution (Alternative B)	
Testing undertaken	**Results**
Optical microscopy of molybdate films	• Very little detail can be seen on any of the samples. All that is visible is the underlying metal substrate. These optical micrographs are similar to the unhardened samples. • The micrograph of the black sample shows that there are cracks present across the whole surface of the film, which indicates why the sample is very fragile and will likely be easily damaged.
X-ray photoelectron spectroscopy (XPS) of molybdate films	• When compared with films produced through the chromic acid method, it appears that the alternative solutions coloured films are 'thinner' than the chromic acid samples.

Analysis indicates that the film formed is on the surface of the stainless steel: unlike INCO which the film becomes integrated with the chromium oxide layer. This demonstrates the need for improvement in binding colour to the substrate. The alternative solutions are also more expensive because they are not used in many industrial applications on any scale.

Continued work on this alternative solution colouring process was undertaken in the second PhD.

3.5.1.2 The Electrochemical Colouring of Austenitic Stainless Steel – second PhD

The second PhD sponsored by Rimex was undertaken during the review period, extended details are included in Appendix 1. The PhD focused on the following objectives:

- To fully understand the colouring processes for austenitic stainless steels in the alternative solution colouring (alternative B)
- To examine suitable oxidising media to help to maximise the adhesion of colour finishes on stainless steels for alternative solution colouring (alternative B)
- To investigate any other colouring systems using environmentally benign chemical constituents, for example trivalent chromium-based.
- To investigate the preliminary scale up of the most successful replacement systems.

Results from the second PhD are summarised in **Table 3-7**. Discussion of each of the alternatives investigated in the second PhD are discussed in more detail in section 3.6.

Table 3-7: Results of the second PhD	
Alternative investigated	**Results**
Alternative 1	• The solutions using simple immersion had rapid degradation • Poor mechanical properties of the interference film make it unsuitable • Intermittently streaks appeared on some of the coloured steel samples
Alternative 2	• The electrolytic solutions had poor film performance and sealing could not be obtained
Alternative 3	• The electrolytic colouring solutions produce interference films but not consistently for reasons that could not be determined • The films also suffered from poor wear resistance
Alternative 4	• These coatings had some potential but are very different in appearance to the colours of INCO material • However, the coatings are dip into tanks and this can result in as uneven finish, they also require significantly higher temperatures, curing at 250°C at 30 minutes which is too slow for manufacture • Unlike INCO CSS the coatings are not iridescent and would not be direct a replacement for the existing INCO product range

3.5.2 Investigation into PVD CSS

3.5.2.1 Overview of PVD CSS technology

As highlighted in the parent AfA, PVD CSS was noted as being the most realistic alternative. Although, PVD CSS manufacture is based on different principles to the electrochemical/INCO colouring of stainless steel. It does not involve a substance that would act as a direct replacement for CrO_3.

PVD encompasses a range of technologies based on the principle of creating a thin titanium-based ceramic layer on the surface of stainless-steel sheets. This process occurs under vacuum conditions and involves generating an electrical potential difference between the stainless steel and a target coating material. The two main types of PVD technologies are distinguished by their deposition mechanisms: 'Evaporation', where the coating material is vaporised, and 'Sputtering', where ions are sputtered after the target material is bombarded by a high-energy source such as plasma.

Through its R&D efforts and consultations with PVD-coated stainless steel manufacturers in China and Taiwan, as well as PVD equipment manufacturers, Rimex identified three specific PVD technologies for applying finishes. Among these, Multi Arc Ion Deposition (a variation of Cathodic Arc Deposition) and Sputtering Deposition were identified as suitable technologies for processing large-sized sheets.

- **Electron Beam Evaporation**: this describes the process by which titanium (Ti) granules are placed in a crucible inside the chamber and are then melted by electron beams. Once liquid, the Ti vaporises and coats the substrate, via attraction to the positive and negative charges of an electric field. Nitrogen and argon are added to the chamber. Argon creates a positive environment, while electrons provide the negative at 700-800 V. This breaks up the molecules on the material's surface, so that titanium nitride can bond to the surface. Before this process, the material would be charged at each end with a positive and a negative to enable equal layering of the titanium nitride. A simplified diagram of the process is shown in Figure 3-2 (a).

- **Cathodic Arc Deposition – Arc Evaporation**: this process uses a bar of titanium as feed, which is placed within an earthed shield. An arc weld of 300 Amps heats the titanium and causes it to evaporate. Titanium ions are released assisting in the adhesion to the substrate, on which an electrical potential difference is applied. This method is likely to release particles and other impurities that will corrupt the CCS's appearance. A simplified diagram of the process is shown in Figure 3-2 (b).

- **Sputtering or Magnetron Sputtering**: this technology involves rotating the substrate in the chamber past a linear target. The titanium target is hit by a 500 V potential to release titanium ions that will deposit on the material's surface. It also needs to be water-cooled. This is a slower method compared to the other two, but it offers more precise control over the thickness of the coating. It offers less control over the strength of the bonding with the substrate, though. A simplified diagram of the process is shown in Figure 3-5 (c).

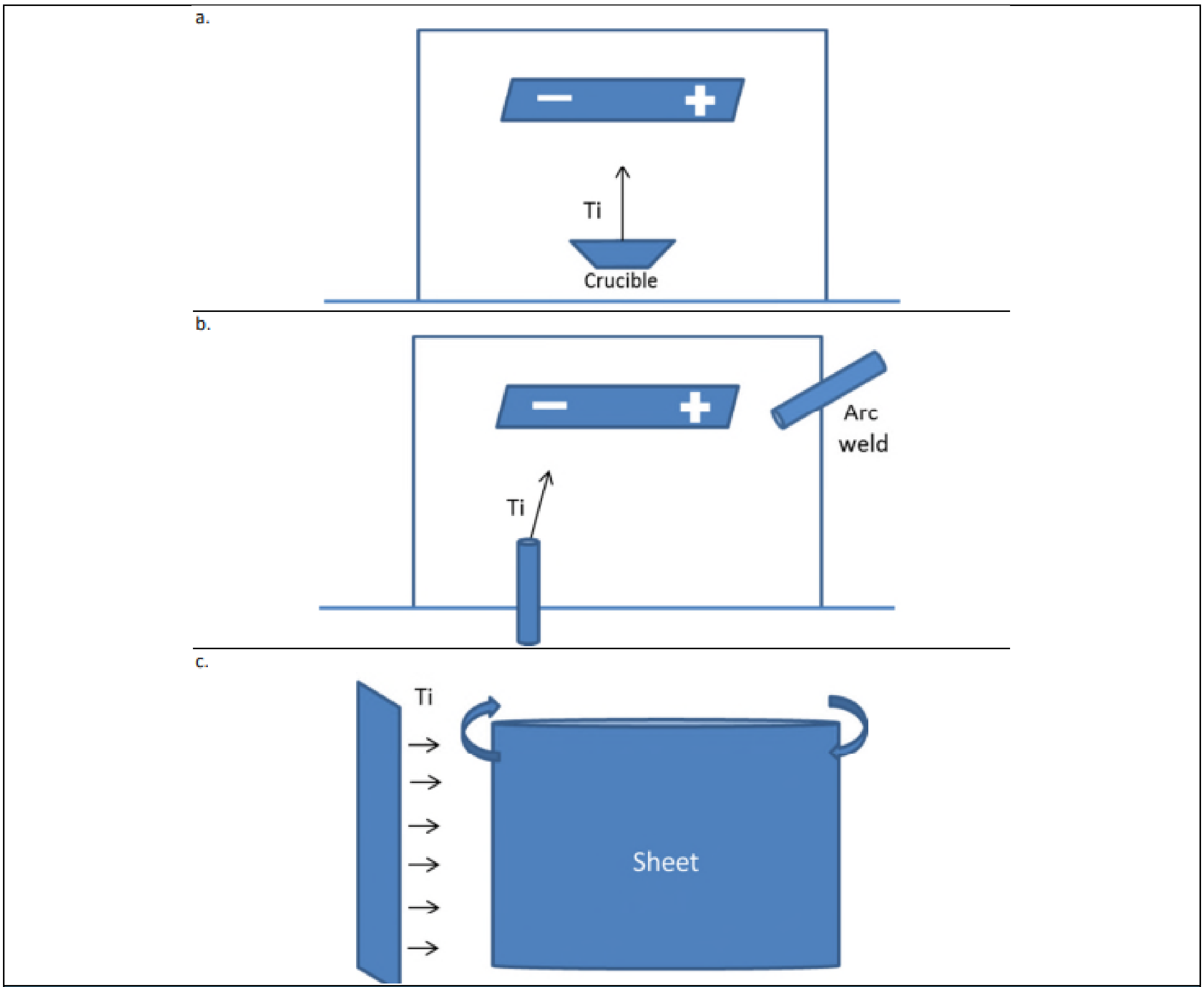


Figure 3-1: PVD technologies: a. Electron beam evaporation; b. Arc evaporation; c. Magnetron sputtering. Source: Rimex

3.5.2.2 Implementation of PVD CSS technology

[redacted] #D, E [redacted]

PVD remains an unsuitable alternative for Rimex.

Although sales of PVD CSS products have grown in UK and Europe, it is however anticipated that the vast majority of PVD is being imported from Asia.

3.6 Assessment of shortlisted alternatives

3.6.1 Alternative 1

3.6.1.1 General description of Alternative 1

After the surface degreasing, the sample to be coloured was immersed in a solution (Alternative 1). The pH of the solution was reduced to pH 1 by slowly adding 37 wt% hydrochloric acid (HCl) to the solution while the pH was monitored by a calibrated pH meter. During immersion the sample was held in place using a stainless steel sample holder and a clamp. The part of the sample in contact with the sample holder remained out of the solution to prevent the sample holder preferentially reacting with the colouring solution.

A Ag/AgCl reference electrode was immersed in the solution and the potential monitored in order for data to be recorded for the production of potential vs time plots. Project immersion times ranged from 30 seconds to 30 minutes.

Following removal from the colouring solution the samples were rinsed with de-ionised water and acetone, and dried using warm air.

3.6.1.2 Availability of Alternative 1

If suitable, it is very likely that there would be sufficient market availability of the alternative to meet Rimex's product volume requirements.

3.6.1.3 Safety considerations related to using Alternative 1

This alternative would be an improvement in terms of the risk to human health and the environment.

3.6.1.4 Technical feasibility of Alternative 1

Initial testing with Alternative 1 revealed that a variety of colours could be achieved within just a few minutes of immersion. However, issues arose with intermittent streaks appearing on some of the coloured steel samples (Figure 3-2). Other observed issues include severe colour change after 10 weeks in an indoor environment.

Analysis using secondary electron imaging (technique in scanning electron microscopy) (Figure 3-3) demonstrated that there is a degradation from coherent oxide to the fractured platelets. No solution was found for the cause of this degradation and preventative measures were unable to be identified. This process was then not pursued further.

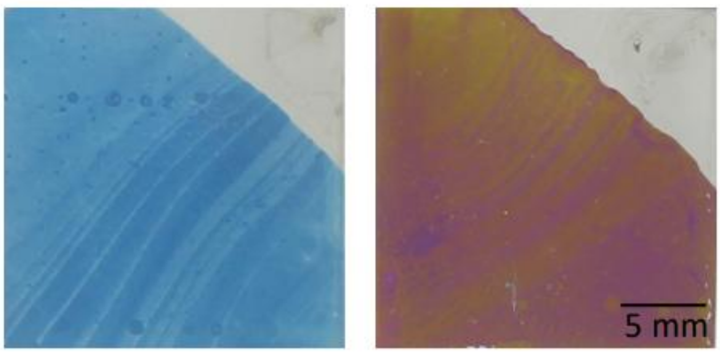


Figure 3-2: Colour streaking from treatment of immersion with Alternative 1

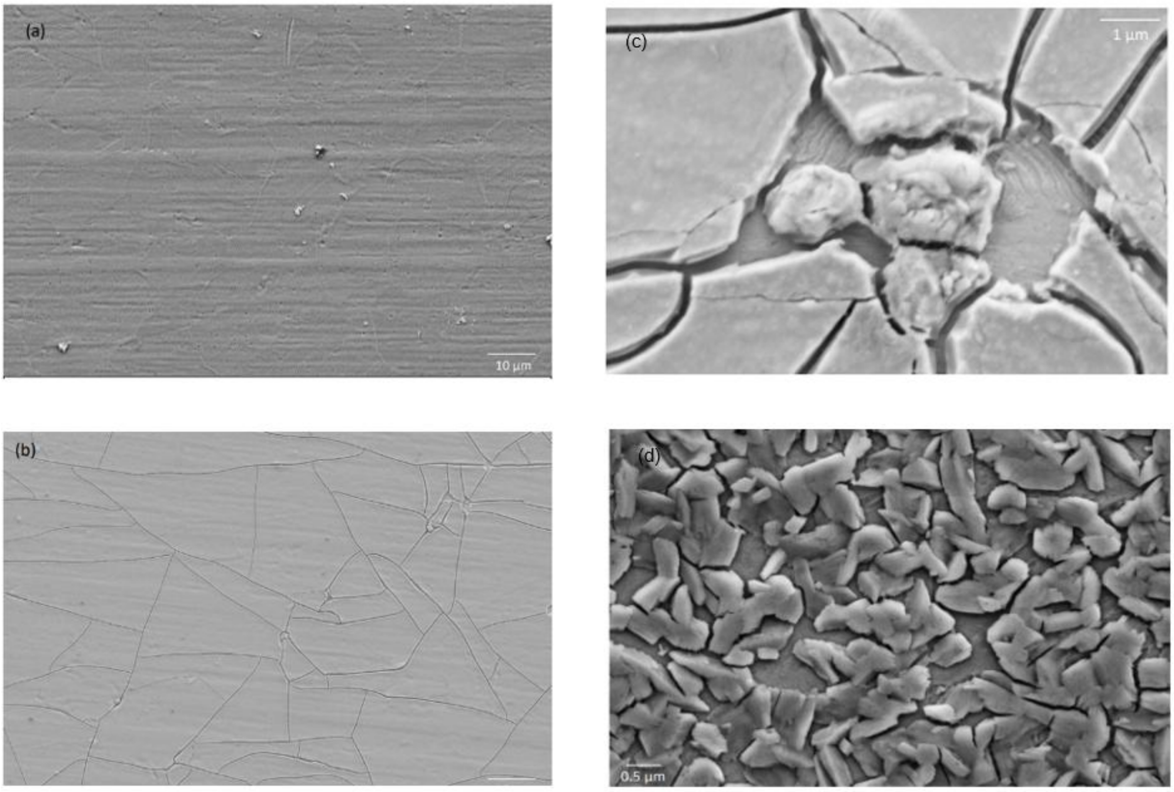


Figure 3-3: Secondary electron SEM images showing the surface morphology of 304 stainless steel samples, (a) 1 day, (b) 37 days (c) 37 days higher zoom and (d) 70 days after colouring by Alternative 1

For these reasons Alternative 1 is not considered to be a technically feasible alternative.

3.6.1.5 Economic feasibility of Alternative 1

If the experimental tests were promising and technical feasibility was likely to be achieved, then Alternative 1 may have been economically suitable.

However, due to the lack of technical feasibility being achieved, economically feasibility remains unproven as several additional steps and challenges may have been identified prior to commercialisation of the alternative.

3.6.1.6 Suitability of Alternative 1 for the applicant and in general

The alternative was not identified as being a suitable alternative due to technical feasibility and performance criteria not being achieved. As summarised in Table 3-7:

- The solutions using simple immersion had rapid degradation
- Poor mechanical properties of the interference film make it unsuitable
- Intermittently streaks appeared on some of the coloured steel samples

There is a high level of uncertainty whether additional R&D into Alternative 1 would result in significant changes to the technical feasibility status of this alternative. This is also supported by Alternative 2 being a different approach with the same type of solution.

3.6.2 Alternative 2

3.6.2.1 General description of Alternative 2

Preliminary electrolytic colouring with Alternative 2 was attempted. The solution and experimental arrangement were similar to that of the simple immersion process (Alternative 1). Instead of pH 1, the solution pH was 2.5, again adjusted using 37 wt% HCl. A counter electrode was immersed in the solution along with the sample and Ag/AgCl reference electrode.

A counter electrode was used and all electrodes were connected to a potentiostat device (an electronic instrument used to control the potential (voltage) difference between a working electrode and a reference electrode in an electrochemical cell device) and software programme to run the experimental parameters which included galvanic pulses.

Prior to colouring, samples were placed into a beaker of acetone in an ultrasonic bath for 5 minutes and dried with warm air. Following colouring, samples were washed in a beaker of deionised water before being rinsed with deionised water. Finally, samples were rinsed with acetone and dried in warm air.

Chemical resistant, Scotch® Core Series 20300 tape was used to mark out an area of the sample of a known size to be coloured, all areas of the sample that were not to be coloured were masked by the tape. A Ag/AgCl reference electrode and lead plate counter electrode with the same surface area as the stainless steel sample, were placed into the colouring solution and held in place with stainless steel sample holders.

Colouring was conducted, in all cases, at ambient temperature and the range of stirrer speeds for all methods of current application remained 0 – 450 rpm. A range of direct current, pulse current and pulse reverse current parameters variables were applied.

The three electrodes were immersed in the colouring solution ensuring that the sample holders did not contact the solution, as they may interfere with the results. Following colouring, stainless steel samples were removed from the solution and rinsed for 10 seconds in two consecutive beakers of deionised water. Finally, the samples were rinsed with acetone and dried in warm air.

3.6.2.2 Availability of Alternative 2

If suitable, it is very likely that there would be sufficient market availability of the alternative to meet Rimex's product volume requirements.

3.6.2.3 Safety considerations related to using Alternative 2

This alternative would be an improvement in terms of risk to human health and the environment.

3.6.2.4 Technical feasibility of Alternative 2

Galvanostatic colouring methods were first investigated but results indicated that there were issues with colour uniformity particularly correlating to increased colour time degradation of the interference film over a period of a few weeks was also witnessed.

Investigation then looked using galvanodynamic colouring methods. The results demonstrating promising colours however there were issues with the mechanical properties. In order to improve wear resistance, the oxide film was sealed in silicate post colouring and treated with a post sealing high temperature treatment. This led to a good range of bright colours using this multi-stage treatment process.

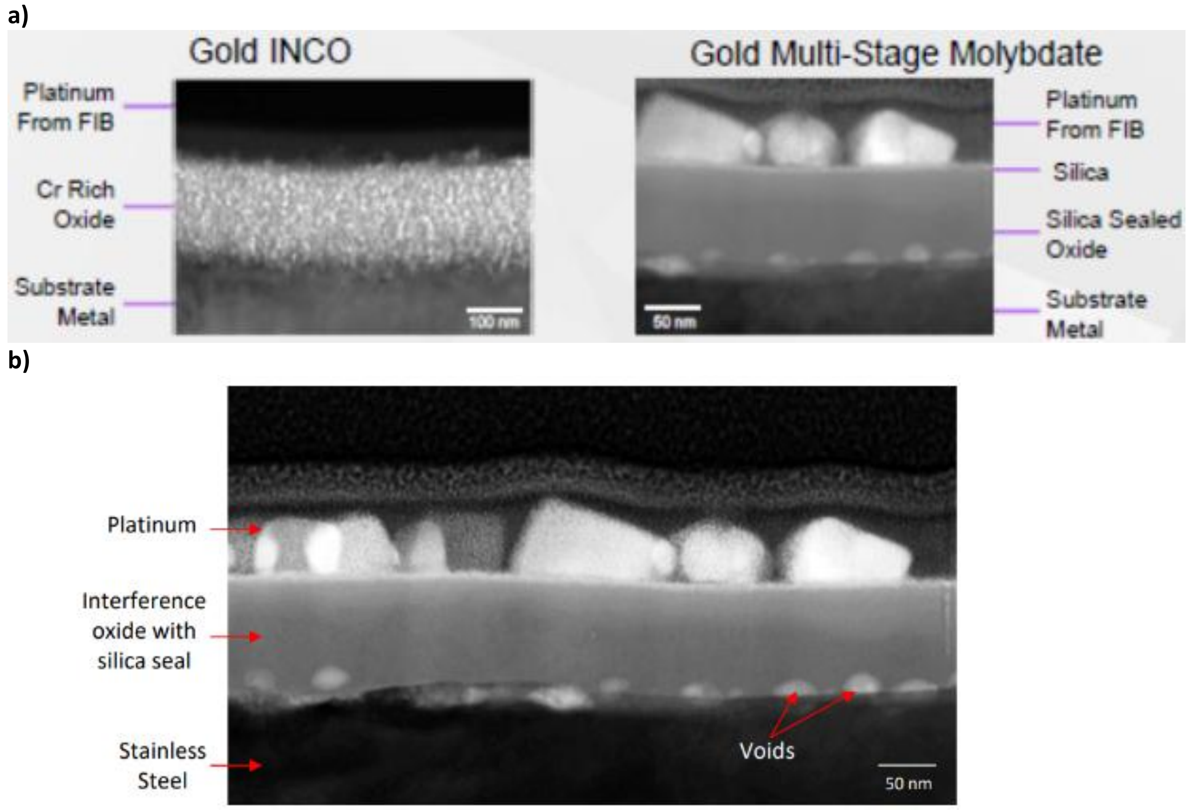


Figure 3-4: TEM analysis of gold INCO CSS and gold multi-stage treated metal

TEM analysis (Figure 3-4) highlighted that the multi-stage Alternative 2 treated metal exhibited a higher density than the INCO sample, with visible voids present at the oxide-substrate interface. This came from the silicate sealing, which provided improvement to wear at the detriment of aesthetics of the coloured metal.

A better protection method would be required for more promising results, but this process was considered an unlikely candidate for continued development with the intention of it replacing the INCO process.

3.6.2.5 Economic feasibility of Alternative 2

If the experimental tests were promising and technical feasibility was likely to be achieved, then Alternative 2 may have been economically suitable.

However, due to the lack of technical feasibility being achieved, economically feasibility remains unproven as several additional steps and challenges may have been identified prior to commercialisation of the alternative.

3.6.2.6 Suitability of Alternative 2 for the applicant and in general

The alternative was not identified as being a suitable alternative due to technical feasibility and performance criteria not being achieved. As summarised in Table 3-7:

- The electrolytic solutions had poor film performance and sealing could not be obtained

There is a high level of uncertainty whether additional R&D into Alternative 2 would result in significant changes to the technical feasibility status of this alternative. This is also supported by Alternative 1 being a different approach with the same type of solution.

3.6.3 Alternative 3

3.6.3.1 General description of Alternative 3

Previous study have demonstrated that chemistries similar to Alternative 3, conversion coatings, can produce interference films. A solution containing substances, based on those that have been used in literature studies was developed and tested.

A counter electrode and a Ag/AgCl reference electrode were immersed in the solution. The 304 stainless steel sample, counter electrode and Ag/AgCl reference electrode were connected to a potentiostat and a software programme to run the experimental parameters. Ranges for the concentration of bath constituents (Alternative 3 solution) and parameters varied during testing, including pulse current and pulse reverse current.

Prior to colouring, samples were placed into a beaker of acetone in an ultrasonic bath for 5 minutes and dried with warm air. Following colouring, stainless steel samples were removed from the solution and rinsed for 10 seconds in two consecutive beakers of deionised water.

Finally, the samples were rinsed with acetone and dried in warm air.

3.6.3.2 Availability of Alternative 3

If suitable, it is very likely that there would be sufficient market availability of the alternative to meet Rimex's product volume requirements.

3.6.3.3 Safety considerations related to using Alternative 3

Although this alternative solution may once have been be considered as resulting in an improvement in terms of risk to human health and the environment, this is not longer the case as one of the components of the solution would result in this alternatively being considered as a regrettable substitution.

The reason for this change is that one of components is now on the candidate list as it fulfils the criteria of being an SVHC. The substance is not currently on the UK REAHC Authorisation List (Annex XIV).

3.6.3.4 Technical feasibility of Alternative 3

Initial results with Alternative 3 demonstrated that it was possible to produce promising interference films on 304 stainless steel. However, for an unknown reason, the promising preliminary results could not be subsequently replicated in later trials.

Table 3-8: TEM analysis of average thickness of interference films

Alternative 3	INCO	Simple immersion
38mm	159nm	53nm

The film thickness (**Table 3-8**) measurements demonstrate the interference films produced using the Alternative 3 process were the thinnest films of the PhD project.

The repeat samples exhibited "edge effects" and demonstrated poor wear resistance. Increasing the bath temperature and adjusting the concentrations reduced edge effects and enhanced the aesthetic quality; however, these adjustments did not improve wear resistance. The poor wear resistance is likely due to large voids running through the interference film in later samples, although the cause of these voids remains unknown.

3.6.3.5 Economic feasibility of Alternative 3

If the experimental tests were more promising than they were and technical feasibility was likely to be achieved, then Alternative 3 may have been economically suitable.

However, due to the lack of technical feasibility being achieved, economically feasibility remains unproven as several additional steps and challenges may have been identified prior to commercialisation of the alternative.

Furthermore, as the development of this alternative may mean that the substance is considered as being a regrettable substitution, this reason would make the economic feasibility of this alternative even more challenging.

3.6.3.6 Suitability of Alternative 3 for the applicant and in general

The alternative was not identified as being a suitable alternative due to technical feasibility and performance criteria not being achieved. As summarised in Table 3-7:

- The electrolytic colouring solutions produce interference films but not consistently for reasons that could not be determined
- The films also suffered from poor wear resistance

There is also a considerable risk that the solution may contain a substance that would lead to this alternative being a regrettable substitution. There is a very high level of uncertainty whether additional R&D into Alternative 3 would result in significant changes to the technical feasibility status of this alternative as one of the key components in the solution would like needed to be considered for substitution.

3.6.4 Alternative 4

3.6.4.1 General description of Alternative 4

Several patents were identified which outlined the use of Alternative 4 coatings in the colouring of stainless steel. One patent, described a how the alternative was used to protect an interference oxide, grown electrochemically, in a chromic sulphuric acid solution.

The alternative is a two-part product, which, when mixed together, initiated the creation of Alternative 4. The two components were mixed, sealed in a bottle and shaken for 30 seconds. The solution was then left for a minimum of 30 minutes, allowing the hydrolysis and condensation reactions to activate. The pot life of the mixed alternative is a maximum of 24 hours.

The alternative was first applied as a dip coating. Samples were immersed into the alternative at a rate of 14 cm min-1, remained immersed for 1 minute, then removed at the same rate. To achieve the immersion and removal rate, a beaker containing the alternative was placed on a scissor jack. The total time to immerse and remove a sample at the desired rate was calculated and a countdown timer used to ensure the alternative was raised and lowered, by hand, to and from the stationary sample in the required time. The CSS sample was held in place using a stainless steel sample holder.

An alternative method of application was also trialled. A pipette was used to deposit a small amount of the alternative at one edge of the coloured sample and a drawdown bar pulled across the sample surface to the opposite edge, in one smooth motion, to evenly distribute the alternative. The drawdown bar was a stainless steel rod with a wire of the same material tightly wrapped around it. The gauge of the wire determines the thickness of the coating layer distributed across the surface. The drawdown bar used was a commercially available 100 µm bar.

Following application of the alternative, it was cured in one of two ways, either in ambient conditions or baked in an oven. Samples cured in ambient conditions were held horizontally on a wire rack in a fume cupboard for 48 hours. Samples cured by baking were placed on a horizontal wire rack in a pre-heated oven at 300 °C for 30 minutes. Following baking the samples were removed from the oven and allowed to cool to room temperature.

3.6.4.2 Availability of Alternative 4

If suitable, it is reasonably likely that there would be sufficient market availability of the alternative to meet Rimex's product volume requirements. The market demand for this alternative has grown and the market availability has grown to meet this demand. However, the demand has led to some availability challenges, Alternative 4 is also more expensive than chromium trioxide.

3.6.4.3 Safety considerations related to using Alternative 4

At the moment this alternative would be an improvement in terms of risk to human health and the environment.

3.6.4.4 Technical feasibility of Alternative 4

These coatings were evaluated using a dip-coating process. Results indicated that this method produced uneven coating thickness across samples and led to noticeable colour variations (Figure 3-5). Additionally, the high-temperature curing process at 250°C for 30 minutes did not cure the coatings quickly enough to prevent redistribution after using the drawdown bar.

Unlike the INCO process, the colour produced by the alternative coating was not iridescent and exhibited significant colour changes after treatment.

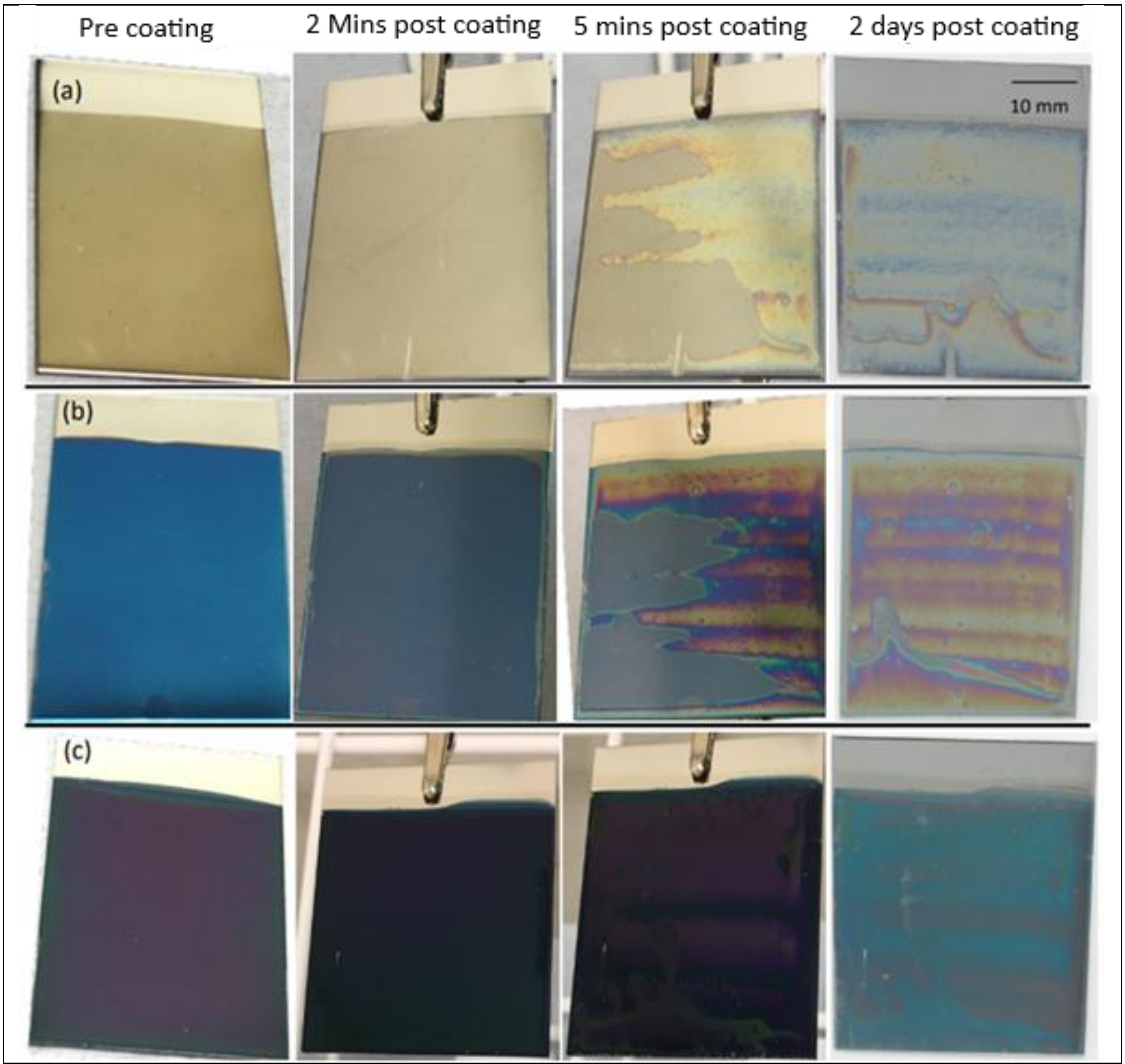


Figure 3-5: Stainless steel samples coloured for (a) 2 minutes, (b) 4 minutes and (c) 6 minutes. The samples were then immersed in the coating solution before being allowed to cure at room temperature for 48 hours.

3.6.4.5 Economic feasibility of Alternative 4

If the experimental tests were more promising than they were and technical feasibility was likely to be achieved, then Alternative 4 may have been economically suitable.

However, due to the lack of technical feasibility being achieved, economically feasibility remains unproven as several additional steps and challenges may have been identified prior to commercialisation of the alternative.

Furthermore, some market availability challenges, the high curing temperature and the reasonably short pot life of the alternative may have presented some economic feasibility challenges.

3.6.4.6 Suitability of Alternative 4 for the applicant and in general

The alternative was not identified as being a suitable alternative due to technical feasibility and performance criteria not being achieved. As summarised in Table 3-7:

- These coatings had some potential but are very different in appearance to the colours of INCO material
- However, the coatings are dip into tanks and this can result in as uneven finish, they also require significantly higher temperatures, curing at 250°C at 30 minutes which is too slow for manufacture
- Unlike INCO CSS the coatings are not iridescent and would not be direct a replacement for the existing INCO product range

There is a possible risk that the coating may in the future contain a substance that could lead to this alternative being a regrettable substitution, although alternative solvents exist and may be suitable which would reduce this risk. There is a high level of uncertainty whether additional R&D into Alternative 4 would result in significant changes to the technical feasibility status of this alternative.

There is also the possibility of some economic challenges associated with this alternative.

3.7 Conclusion on shortlisted alternatives

Consider time and effort was invested in R&D as part of the two PhD project. These projects have not resulted in a suitably alternative being identified. At the moment the most promising alternative identified in the original application, PVD, would still remain the most realistic alternative.

Although PVD CSS is emerging as an alternative to INCO CSS. It delivers a good-quality, visually appealing finish at a similar or lower price, and its adoption is accelerating as more suppliers offer and promote it. This cost-effective and scalable solution is attractive to architects and designers seeking innovative materials without compromising on aesthetics.

However, while PVD CSS excels in terms of appearance and affordability, it cannot match the proven 60-year history of proven durability and reliability of INCO CSS in certain demanding applications. The thin film nature of PVD coatings preserves the base metal's properties but also makes them more vulnerable to severe abrasion or impact. As a result, repairs can be more challenging compared to thicker, conventional coatings.

Despite the growing demand for PVD CSS, it cannot fully replace INCO CSS. INCO CSS remains essential for certain applications due to its proven durability, reliability, and legacy specifications. Its superior performance in external cladding and other demanding environments ensures continued demand, even as PVD CSS gains market share. It is also not an economically feasible alternative for Rimex. Therefore, there will be a long term (>25 years) need for INCO CSS to be produced and an extra long review period will help Rimex justify the business investments and equipment lifecycles.

3.7.1.1 Results of both PhDs

None of the processes investigated in either PhD project were able to match the aesthetic quality, mechanical performance, and environmental benefits of the INCO process using chromium trioxide. No suitable alternatives were identified to replace chromium trioxide in INCO colouring. After sponsoring two PhD studies #F over a span of seven years and investing into other R&D activities and staff time (Rimex have so far invested ca. #F into the investigation of alternatives), Rimex have concluded that all viable options have been exhausted for the time being.

In addition to the summary of the R&D set out above, Appendix 1 is an abridged version of the most recent PhD study. Due to the information being directly linked to the R&D conclusions the appendix is claimed as currently being confidential.

4 SOCIO-ECONOMIC ANALYSIS

4.1 Continued use scenario

4.1.1 Summary of substitution activities

In the previous AfA that Rimex submitted for Cr(VI), PVD CSS was identified as an alternative different type of method to the INCO CSS process. PVD CSS is already a commercial alternative, with production predominantly in the Asian sector. Prior to 2021 there was a strong demand for INCO CSS, since this time demand has decreased and this is attributed to several factors. Since 2020, Rimex have noted that the market is trending towards the use of imported PVD CSS as a cheaper alternative. This is however, without considering technical drawbacks for the PVD CSS process in comparison with INCO CSS.

Actions from the previous AfA [redacted] #D, E [redacted] Therefore, manufacturing PVD CSS is not an alternative substitution option for Rimex and it is not an alternative that fulfils the existing key performance critical in external cladding and other demanding environmental uses.

Further to the inoperability of the PVD plant, existing attempts have been made to research for alternatives to Cr(VI) with the first project undertaken from October 2013 to October 2016 and the second project was undertaken from October 2016 to September 2019. After six years of research, it was concluded that no viable alternative was found for the time being.

4.1.2 Conclusion on suitability of available alternatives in general

The AoA has found that despite the growing demand for imported PVD CSS, it cannot fully replace INCO CSS. INCO CSS remains essential for certain applications due to its proven durability, reliability, and legacy specifications. It has superior performance in external cladding and other demanding environments which ensure continued demand, while considering the increasing market share of PVD CSS. INCO CSS will always be needed.

4.1.3 Substitution plan

4.1.3.1 Factors affecting substitution

There has been a decrease in INCO CSS sales / manufacture by Rimex UK since 2020 due to a fall in UK / EU economies and especially the construction sector. Several factors have impacted demand; these include the COVID pandemic and other geopolitical impacts. These have had an impact on the cost of energy[10], cost of raw materials (including steel[11]) and have impacted the demand for construction

[11] Price History of Steel, Tables and Charts: USA, China, Western Europe and World Export. Available here: http://steelbenchmarker.com/history.pdf

materials[12] (See Annex 4) and wider sectors and consumer confidence[13] where other products where INCO CSS is used.

There are more companies offering and importing PVD CSS sheet products as they look for business in a depressed market. Following decreases in the demand for INCO CSS since 2020, Rimex have noted that the market is trending towards using PVD CSS. One of the main reasons for this is due to it being cheaper for customers to buy from Asia or via a distributor who sources from Asia. Although Rimex also distribute PVD CSS, there is still a significant market demand for INCO CSS products and Rimex believe this will continue and potentially increase as market conditions improve, with the insolvency of INCO CSS manufacturers in Europe and the introduction of CBAM in Europe in 2026 and to follow in the UK[14] in 2027.

The substitution plan is impacted by a combination of factors affecting the implementation of the alternative, these include:

- Functionality, chemical technicality and ability in the alternative processes of producing CSS to meet the performance requirements of INCO CSS;
- Availability of alternatives;
- Suitability of the alternative into current process;
- Economic feasibility, which includes the capital and operational cost of moving to an alternative;
- Impact on downstream users, and where they might need to source INCO CSS in the event of discontinuation;
- A substitution process in line with current production demand.

Imported PVD CSS is presently being sold on the market, but substitution-wise however, PVD CSS would not be able to substitute existing uses for INCO CSS, such as external use of CSS.

Should the production of INCO CSS cease, existing downstream users would be directly impacted by this. This would negatively impact the UK market for INCO CSS (as well as the EU market from Rimex's sales to the EU) and redirect downstream user consumption to other markets around the world who are still producing INCO CSS, such as the US. In this scenario Rimex would lose [redacted] (£0.5-5 million) in annual turnover. This is while considering economic challenges following from 2021; Despite a slowdown in sales, there is still demand for INCO CSS. Conversely, although PVD CSS is increasing in turnover for Rimex year-on-year from 2021 [redacted] (£0.5-5 million), the profit made by Rimex is significantly smaller around, [redacted]

[redacted]

This ultimately impacts on substitution with PVD CSS, in terms of manufacturing and producing CSS. Economically, this is infeasible for Rimex. Substitution with PVD CSS still highlights the technical challenges of aligning PVD properties with INCO products as existing customers have specific requirements relating to the performance of INCO CSS. Instead, the costs of importing PVD CSS from

12 ONS, Quarterly new orders in the construction industry. Available at: https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/datasets/newordersintheconstructionindustry/current

13 UK Business and consumer confidence: Economic indicators. Available at: https://commonslibrary.parliament.uk/research-briefings/sn02817/

14 UK steel industry backed by major new trade measure and strategy - GOV.UK

Asia far outweigh manufacturing costs regarding affordability, with which Rimex have been doing so since 2013.

Rimex have sponsored two R&D projects to investigate alternatives to using CrO_3. Results ultimately showed that none of the processes investigated in either PhD project were able to match the aesthetic quality, mechanical performance, and environmental benefits of the INCO process. It was concluded that no suitable alternatives were identified to replace CrO_3 in INCO colouring. Rimex have concluded that all viable options have been exhausted for the time being.

This implies the need for an extra-long 25-year review period to allow for the crystallisation of emerging technologies and discoveries in the academic and industrial field. An extra-long review period would also provide Rimex with business confidence to make investments in their site to replace their existing colouring and electropolishing lines with new equipment where the service live of such lines is typically 25-years or more.

4.1.3.2 List of actions and timetable with milestones

Multiple test candidates to replace Cr(VI) as part of INCO CSS have previously been screened and investigated. Rimex currently have no specific timetable with milestones having already funded two PhD projects into identifying alternatives at consider time, effort and expenses for a SME. Generally, Rimex will be utilising the extra-long review period to monitor and conduct more research into alternatives to CrO_3. Any alternatives will be assessed against the same technical feasibility criteria.

#D, E [redacted]

4.1.3.3 Monitoring of the implementation of the substitution plan

The research previously conducted by Rimex is described in the previous application and as part of the two Rimex funded PhDs. Similar detailed information may be produced and archived throughout the research and development stages as part of future assessments during the 25-year review period.

4.1.3.4 Conclusions

Rimex's recent costly attempts at R&D for alternative Cr(VI)-free processes have resulted in limited beneficial outcomes and these would not benefit INCO CSS production. Given the limited state of available potential alternatives to CrO_3 for INCO CSS, it is challenging for a detailed substitution plan and series of next steps to be develop and implemented at this time.

Recovery in INCO CSS turnover would help to strengthen business confidence in the long-term demand for CSS and this would help to fund future R&D into alternatives.

The inability to continue producing INCO CSS would affect Rimex with significant economic and social impacts (to be discussed in later sections). The economic impacts would result in a loss of revenue #D, E [redacted] (£0.5-5 million) per year, in turn impacting turnover and profit at Rimex USA, Rimex AUS, RDEU, due to the Group's consolidated financial position. On top of this, the expected number of employees being made redundant would be costed at #D, E [redacted] (20-50).

4.1.4 R&D plan

The AoA has concluded that there is no alternative to INCO CSS. There are multiple stated "potential alternatives", however, there is currently a resounding conclusion that there are no present alternatives to Cr(VI) in the manufacturing of INCO CSS and that further R&D would be required to identify an alternative. More importantly there is a lack of information and literature on research regarding the integration and use of these methods at industrial scale. Previous research attempts at Cr(VI) – free INCO processes have all failed to yield any desirable results. This means that a longer review period would be required for Rimex to continue producing INCO CSS whilst still being able to conduct/fund future research attempts at finding a Cr(VI) – free INCO manufacturing process or finding another process which produces CSS with the same properties as INCO CSS.

Indeed, the challenging nature of substituting Cr(VI) with other alternatives is also more broadly shown by the number of applications for authorisation submitted within both the UK and EU.

4.2 Market analysis of products manufactured with the Annex XIV substance

INCO CSS has been undersold over the past four years, since 2021, due to economic challenges following COVID-19 and the impact of the Ukraine war. The majority of INCO CSS is used in architectural applications, but with construction activity slowing over the past three years, demand has declined. However, production capacity remains available.

Despite the slowdown in sales, there is still demand for INCO CSS as seen in **Table 4-1**, the table shows that in [redacted]. Competitors are not in a position to install new INCO CSS production lines, as these are complex processes requiring significant investment and regulatory approvals. Instead, they find it easier to import PVD CSS into Europe. In Europe, only a few manufacturers of INCO CSS remain.

Table 4-1: Coloured stainless-steel data 2021-2025*

Year	INCO (Colourtex)		PVD (T22)		Total of all CSS	
	Turnover	Metric tonnes sold	Turnover	Metric tonnes sold	Turnover	Metric tonnes sold
2021	[redacted]					
2022						
2023						
2024						
2025						
Average						

As shown in **Table 4-1**, despite the increasing growth of PVD CSS, the overall sales of all coloured stainless-steel is decreasing and has been since 2021. This decline in sales is driven by multiple factors, including the post-COVID economic downturn and the Ukraine war, which have significantly impacted the UK and Europe, with the German economy being particularly affected. Economic woes have caused customers to switch from heavier to lighter gauges in certain industry sectors such as lifts in order to save money.

Another reason for the decline is due to the reduction in the price of stainless-steel since 2021. The reduction of stainless-steel prices has pushed mills to cut production in response to financial losses and reduced underlying customer demand[15]. These are other related impacts have contributed to a reduction in turnover and sales.

[15] Stainless Steel Market Dynamics and Outlook, British Stainless Steel Association, available here: https://bssa.org.uk/stainless-steel-market-dynamics-and-outlook

Despite the decline in sales, there remains strong demand for both CSS products, as they continue to be specified by architects, designers, and engineers. Some legacy specifications explicitly require INCO CSS, and it is likely to be chosen for applications such as external building cladding due to its superior reliability.

Looking ahead, demand for PVD CSS is expected to grow as more suppliers introduce it to the market, stock it, and promote its use. While INCO CSS will continue to be valued for its reliability and unique properties, its market share will be expected to be smaller than that of PVD CSS, primarily because only three manufacturers remain in Europe including Rimex. The other two manufacturers of INCO CSS are Steel Color Spa of Italy and Inox Color GmbH of Germany. However, these two companies may no longer have authorisation for use of chromium trioxide, but the current EU REACH Restriction intention for chromates may remove REACH Authorisation pressures on these companies. If these companies were to close INCO CSS operations there would be plenty of demand for the product that Rimex, with its Authorisation, would want to service. There remains a market and value for INCO CSS.

4.3 Risks associated with continued use

4.3.1 Impacts on humans

Chromium trioxide as covered by this combined AoA/SEA was included into Annex XIV of Regulation (EC) No 1907/2006 due to its intrinsic properties. Chromium trioxide is classified as a Carcinogen 1A and a Mutagen 1B under the CLP Regulation. The most important route of exposure and target organs are inhalation causing lung cancer and oral exposure causing intestinal cancer. The substance is also classified as a Skin and Respiratory Sensitiser 1 and is a Reproductive Toxicant 2.

The hazard evaluation follows recommendations given by RAC[16]:

- For assessing carcinogenic risk, exposure-risk relationships are used to calculate excess cancer risks; and
- As mutagenicity is a mode of action expected to contribute to carcinogenicity, the mutagenic risk is included in the assessment of carcinogenic risk, and low risks for mutagenicity are expected for exposures associated with low carcinogenic risks.

The risks associated with continued used during the requested review period are discussed in the sections below. Although there will be an ongoing risk to human health, as shown in the CSR, the risk to human health and humans-via-the environment from the activities is low.

4.3.1.1 Overview of exposure scenarios

The use chromium trioxide takes place at Rimex's site in Enfield, which is a specialised site with a mix of technical, organisation and personal-protection-based measures in place to reduce workplace exposures. Use of Cr(VI) as part of INCO CSS manufacturing operations is contained to 286 days per year where only necessary and authorised personnel are allowed to access the shop floor to reduce exposure. The site adheres to best practices to reduce workplace exposures and environmental emission to as low a level as technically and practically feasible.

Table 4-2 lists all the exposure scenarios (ES) and contributing scenarios assessed in the CSR.

[16] ECHA Website: https://echa.europa.eu/documents/10162/21961120/rac_35_09_1_c_dnel_cr-vi-_en.pdf/8964d39c-d94e-4abc-8c8e-4e2866041fc6; assessed in March 2021

Table 4-2: Overview of exposure scenarios and their contributing scenarios

Identifiers	Titles of exposure scenario and the related contributing scenarios	Environmental release category (ERC)/ Process category (PROC)
ES1 - IW1	Use at industrial site - manufacture of coloured stainless steel.	
Environmental contributing scenario		
ECS 1	Use of chromium trioxide as an oxidising and hardening agent in the manufacture of coloured stainless steel.	ERC 5
Worker contributing scenarios		
WCS 1	Colouring line operator	PROC 13
WCS 2	End of line operator	PROC 13
WCS 3	Packaging unit operator*	No specific Cr(VI) related task
WCS 4	Colouring plant chemist and technician	PROC 4, PROC 8b, PROC 9, PROC 13, PROC 15, PROC 28
WCS 5	Maintenance manager and maintenance worker	PROC 28
WCS 6	Supervisor/Foreman	No specific Cr(VI) related task
WCS 7	Colouring plant manager	No specific Cr(VI) related task
*including activities like forklift driving, mirror polishing, etching, coating and packing; Y (indirect): exposure via Cr(VI) present in air of production hall, but these workers have no direct contact to Cr(VI) containing material/solids/liquids		

4.3.1.2 Worker assessment

The CSR provides details of the approach and assumptions applied to the underlying calculation of exposures and risks from the use of chromium trioxide. The calculated exposure levels and associated excess cancer risks are presented below. For further information on their derivation see the CSR.

Workers are exposed to chromium trioxide via inhalation while there is no risk of oral exposure. Workers wear protective gloves and respiratory equipment, despite these measures a very conservative approach to exposure was taken. Therefore, the main focus of the quantitative exposure estimation and risk characterisation for the worker population is on the carcinogenic effects of inhalation exposure, i.e. lung cancer.

Table 4-3 outlines the main processes associated with the formulation of chromium trioxide products.

Table 4-3: Summary of tasks involving exposure to chromium trioxide during coating activities

WCS#	Description of tasks	Concentration of chromium trioxide (Cr(VI))	Operational conditions	Frequency	Duration
Worker contributing scenario(s)					
WCS 1	Operating colouring line – several activities	[redacted] #B	LEV	Up to 240 days per year	Up to 480 minutes
WCS 2	End of line operator	[redacted]	LEV	Up to 240 days per year	Up to 480 minutes
WCS 3	Operators of Packaging unit and activities	N/A	-	240 days per year	480 minutes
WCS 4	Manual decanting of chromium (VI) trioxide flakes into a mesh basket	Pure product	LEV, RPE	72 days per year	16 minutes

Table 4-3: Summary of tasks involving exposure to chromium trioxide during coating activities					
WCS#	**Description of tasks**	**Concentration of chromium trioxide (Cr(VI))**	**Operational conditions**	**Frequency**	**Duration**
	Dissolution of solid CrO_3 in tanks	Pure product	LEV, RPE	72 days per year	20 minutes
	Re-filling of bath-liquids	Pure product	LEV, RPE	72 days per year	15 minutes
	Cleaning of solid CrO_3 with a hose	Pure product	LEV, RPE	30 days per year	30 minutes
	Cleaning of equipment	[redacted]	LEV, RPE	30 days per year	30 minutes
	Tank sampling	[redacted]	LEV, RPE	48 days per year	15 minutes
	Laboratory analyses of the tank solutions with LEV	[redacted]	LEV	48 days per year	15 minutes
	Addition of mist suppressant	N/A	LEV	48 days per year	2 minutes
	Operating effluent treatment plant	[redacted]	-	240 days per year	240 minutes
	Tank fill up	[redacted]	LEV	240 days per year	45 minutes
	Maintenance	[redacted]	LEV	240 days per year	480 minutes
	Manual intervention at the filter press	[redacted]	LEV	240 days per year	60 minutes
WCS 5	Maintenance manager and maintenance worker	[redacted]	LEV	20 days per year	120 minutes
WCS 6	Supervisor/Foreman	N/A	LEV	240 days per year	240 minutes
WCS 7	Plant Manager	N/A	LEV	-	-

Source: Rimex CSR

CT = Chromium Trioxide; LEV = local exhaust ventilation, PROC = process category, WCS = worker contributing scenarios

LEV are present on chemical treatment baths, therefore whenever an activity/task/person is in the vicinity of a tank an LEV is present supervisor/foreman/plant managers do not spend their time in the vicinity of tanks during their normal roles

As the handling of substances in laboratories for quality control purposes under controlled conditions and in amounts below 1 t/year falls under the exemption for authorisation for the use of substances in scientific research and development[17] according to REACH Art. 56(3), no exposure assessment is performed for the laboratory analysis of treatment bath samples

Worker protection measures and environmental controls

Rimex implement a series of technical and organisational measures as part of their processes, in order to minimise exposure of employees and the environment to chromium trioxide. These are described in further detail within the CSR, these include:

- Technical measures:
  - Air
    - Chemical treatment baths are equipped with LEV

[17] Q&A Reference number: ID 0585; https://echa.europa.eu/de/support/qas-support/browse/-/qa/70Qx/view/ids/585-1442-1443-1498-1565; assessed in March 2021

        - No waste air treatment
    - Wastewater
        - Wastewater occurs from bath solutions, water from drag-out tanks, rinsing water, cleaning water, liquid from secondary containment pits, and liquid hazardous waste from the laboratory
        - Cr(VI)-containing wastewater is gathered and treated on-site in a reduction facility, where Cr(VI) in wastewater is reduced to Cr(III) by addition of a reduction agent (sodium metabisulphite ($Na_2S_2O_5$)), followed by precipitation with lime
        - Reduced wastewater is sent to an external sewage treatment plant (STP)
    - Soil
        - The indoor and outdoor surfaces where chemicals are handled are sealed and if chemicals and solid waste containing Cr(VI) are stored outside then it is only in closed containers
        - Tanks are surrounded by secondary containment pits, and liquids collected in the pit are sent to the wastewater collection tank
- Organisational measures:
    - Regular monitoring programmes are implemented for monitoring of occupational exposure to chromium (VI)
    - Cr(VI) air emission measurements are regularly performed at identified exhaust stack(s) where the process emissions are released
    - The effectiveness of the risk management measures and operational conditions in place are regularly reviewed, and, as applicable, measures are introduced to further reduce exposure and emissions, as applicable
    - The LEV systems installed are inspected and maintained according to the manufacturer´s specification
    - The provision of PPE for the workers is organised by a designated responsible person.
    - The conditions of the PPE are checked regularly.
    - Standard procedures are available for use and maintenance of respiratory protective equipment (RPE) (including procedures for fit testing of RPE masks which are applied in accordance with relevant standards)
    - A program of PPE management is implemented on site which includes PPE selection, training for correct wear/removal of the PPE, storage of PPE, cleaning or renewal and distribution of the PPE, communication via workplace signage or working instructions at the workplace
    - Training for handling of dangerous substances (environmental, health and safety training) is given regularly, by responsible facilitators.
    - On the job training is given and activity-related work instructions are available on how to carry out specific tasks, e.g., for opening lines in case of maintenance activities.
    - Implementing best practices measures such as reducing drag-out from surface metal treatment tanks with a focus on maximising the retention of process chemicals in the tank and reducing the volume of liquid carried over to rinsing stages
    - Safety data sheets or other adequate workplace instructions are available at workplaces with exposure to hazardous substances
    - Specific procedures are in place to minimise exposure, e.g., to avoid splashes.

  - Chemical products are stored in a designated area
  - Effective cleaning practices are implemented to prevent surface contamination in the vicinity of the vessels
  - Reduction of Cr(VI) in wastewater is controlled regularly by Cr(VI) measurements
  - Batches of reduced wastewater are discharged only after confirmation of Cr(VI) reduction to a concentration below the permitting limit (in accordance with the local regulatory requirements)
- Workers operating near chromate 'hot spots' wear appropriate personal protective equipment (PPE), as shown below, in **Table 4-4**; and
  - The conditions of the PPE are checked regularly
  - Workers obtain training and instructions on the proper use of PPE and RPE
  - Rimex provides their employees with work clothes and a washing machine is available on site for employees to use

Table 4-4: Summary of tasks involving exposure to chromium trioxide during downstream user activities		
#	Description of tasks	PPE/RPE applied
WCS 1	Operating colouring line – several activities	Overall, chemical resistant gloves, eye protection
WCS 2	End of line operator	Overall, chemical resistant gloves, eye protection
WCS 3	Operators of Packaging unit and activities	Overall, chemical resistant gloves
WCS 4	Manual decanting of chromium (VI) trioxide flakes into a mesh basket	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Dissolution of solid CrO_3 in tanks	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Re-filling of bath-liquids	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Cleaning of solid CrO_3 with a hose	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Cleaning of equipment	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Tank sampling	Protective apron, chemical resistant overall, chemically resistant gloves, Respiratory Protection (with APF of 40)
	Laboratory analyses of the tank solutions with LEV	Overall, latex gloves, eye protection
	Addition of mist suppressant	Overall, latex gloves, eye protection
	Operating effluent treatment plant	Overall, latex gloves, eye protection
	Tank fill up	Overall, latex gloves, eye protection
	Maintenance	Overall, latex gloves, eye protection (adapted to the situation)
	Manual intervention at the filter press	Overall, chemical resistant gloves
WCS 5	Maintenance manager and maintenance worker	Overall, latex gloves, eye protection (adapted to the situation)
WCS 6	Supervisor/Foreman	Adapted to the working situation
WCS 7	Plant Manager	Adapted to the working situation
Source: Rimex CSR APF = Assigned Protection Factor		

Exposed worker population

As can be determined from the tables in this section of the report and the CSR, different operator rules are involved in the contributing scenarios. It should also be recognised that this is a conservative estimate, because where the number of workers performing each task is given as a range (**Table 4-5**); the upper limit in each range is used in the calculations provided in this SEA.

As noted in the CSR, solid chromium trioxide is decanted into the tanks, this activity takes place around 72 times per year and last for around 16 minutes while there is a maximum of 286 CSS manufacturing days per year.

Section 9.2 of the CSR provides a detailed description of tasks and exposure risks. The number of bystanders at the site engaged in manufacturing activities is low: the manufacturing of INCO CSS is organised as a batch-wise process. On these days access to the shop floor and other relevant areas is restricted to only those personnel involved in production process.

Therefore, the chromium trioxide INCO CSS production zones are not permanent working areas. Workers only access these areas where required. This is evident from the information provided in **Table 4-3**.

Combining the data gives the results presented in **Table 4-5**, which presents the excess lung cancer risks to workers, according to calculations in the CSR. The risks were calculated using modelled values. The measured values were reported as a range of 90th percentile values calculated for the site. In both tables, the excess cancer risk refers to a working life of 40 years. This will have to be adjusted in subsequent calculations to account for the requested review period (12 years).

Table 4-5: Allocation of personnel at Rimex's Enfield site and excess lung cancer risk

Operator type	Number of operators	Risk]
WCS 1: Colouring line operator	3	2.77E-03
WCS 2: End of line operator	5	3.75E-03
WCS 3: Packaging unit operator*	5	1.11E-04
WCS 4: Colouring plant chemist and technician	2	1.25E-03
WCS 5: Maintenance manager and maintenance worker	4	6.08E-05
WCS 6: Colouring supervisor/foreman	2	1.10E-03
WCS 7: Colouring plant manager	1	2.10E-05
Total operators	**22**	

Source: Information from CSR

*RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to 1 µg/m^3 Cr(VI) relates to an excess risk of 4x10^{-3} for workers, based on 40 years of exposure; 8h/day; 5 days/week.

Humans via the environment

In relation to oral exposure of humans via the environment at local and regional level, it has to be acknowledged that chromium trioxide solutions are used in controlled environments. Prior to the release from the site there is no treatment of air while wastewater containing Cr(VI) is gathered and treated on-site in a reduction facility, where Cr(VI) in wastewater is reduced to Cr(III) by addition of a reduction agent (sodium metabisulphite (Na2S2O5)), followed by precipitation with lime. Reduced wastewater is sent to an external sewage treatment plant (STP).

Emissions to the environment from Rimex's operations are therefore expected to be low. In relation to oral exposure of humans via the environment, it has to be acknowledged that Cr(VI) is rapidly reduced to Cr(III) in many environmental compartments.

Nonetheless, exposure via ambient air and oral exposure (through ingestion of drinking water and consumption of fish) has been considered at both regional and local scale.

At the local level, the inhalation exposure of humans via the environment has been assessed on the basis of site-specific data on releases to air. To assess the effects of oral exposure at the local level, only exposure via drinking water and fish has been taken into account. Oral exposure happens predominantly by means of drinking water and consumption of fish.

Release fractions to air are low, the release fraction is calculated as being 4.78×10^{-3} based on emission for the years 2019-2024 (excluding outliers), a release factor of 13.7 kg/year is also calculated in the CSR. Release fractions to water are lower, the release fraction is calculated as being 2.35×10^{-6} and a release factor of 0.00674 kg/year is calculated in the CSR. The release to soil is negligible as there are no direct releases to soil.

No regional assessment has been carried out as it can be assumed that Cr(VI) from any source will be reduced to Cr(III) in most environmental situations and therefore the effects of Cr(VI) as such are likely to be limited to the area around the source, as described in the EU Risk Assessment Report for chromates (European Chemicals Bureau, 2005). The approach to not perform a regional assessment for human Cr(VI) exposure via the environment as part of AfAs for chromate uses was also supported in compiled RAC (Risk Assessment Committee) and SEAC (Socio-economic Analysis Committee) opinions, as described for example in the *Opinion on an Application for Authorisation for Use of Chromium trioxide for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films* (ID 0043-02). This states that regional exposure of the general population is not considered relevant by RAC[18].

Information about the local exposure of humans via the environment and Rimex's calculated risk characterisation ratios (RCR) are summarised in **Table 4-6**.

Table 4-6: Exposure concentrations and excess cancer risk estimates for humans via the environment – on local scale (applicant's site)

Inhalation			Oral			Combined
Local Cr(VI) PEC in air [µg/m³]	Excess lung cancer risk [1/(µg/m³)][a]	Inhalation risk	Oral exposure (water and fish) [µg Cr(VI)/kg x d][b]	Excess cancer risk for tumours of the small intestine [1/(µg/kg bw/day)][c]	Oral risk	Combined risk
1.04×10^{-02}	2.9×10^{-02}	3.02×10^{-04}	5.37×10^{-05}	8×10^{-04}	4.30×10^{-08}	3.02×10^{-04}

[a] RAC dose-response relationship based on excess lifetime lung cancer risk (ECHA, 2013): Exposure to 1 µg/m³ Cr(VI) relates to an excess risk of 2.9×10^{-2} for the general population, based on 70 years of exposure; 24h/day.

[b] combined exposure from drinking water (1.25E-7 µg Cr(VI)/kg x d) and fish consumption (7.2E-9 µg Cr(VI)/kg x d)

[c] RAC dose-response relationship based on excess cancer risk for tumours of the small intestine (ECHA, 2013): Exposure to 1 µg/m³ Cr(VI) relates to an excess risk of 8x10-4 for the general population, based on 70 years of exposure; 24h/day.

Overall, the figures show that the risks calculated for humans exposed via the environment are low, even when conservative assumptions are used in the modelling approaches. It must be recognised that Rimex perform reductive treatment wastewater, leading to quantitative reduction of Cr(VI) release to the environment where it will rapidly reduce to Cr(III).

Local exposure

For local exposure assessment, workers near the site who are not directly exposed to chromium trioxide (or Cr(VI)) along with the population living in the vicinity of it have to be considered. **Table 4-7** below summarises the number of people estimated to be locally exposed in Enfield and **Figure 4-1** shows, the notional circle area of the 1 km radius around the site.

[18] RAC/SEAC "Opinion on an Application for Authorisation for Use of Chromium trioxide for surface treatment of metals such as aluminium, steel, zinc, magnesium, titanium, alloys, composites and sealings of anodic films", consolidated version, 2016; https://echa.europa.eu/documents/10162/658d42f4-93ac-b472-c721-ad5f0c22823c

Table 4-7: Total number of workers and residents locally exposed in Enfield			
Rimex directly exposed workers	Residents[1]	Workers[2]	Total[3]
22	5,550	4,500	10,072

[1] In the previous application the local population was calculated as being 5,550

[2] Estimated number of local workers

[3] The typical assumption of a local population is 10,000 per site. As shown in Figure 4-1 a reasonable proportion of the surrounding area consists of warehouse and retail parks (ca. 35%), water, fields, woodlands and greenspaces (ca. 25%) and housing makes up ca. 40%. Using 10,000 or 10,072 may be a reasonable assumption of the local population within the 1 km circle.

Figure 4-1: Location of Rimex's Enfield site (via Google maps)

Health impacts

Under the Applied for Use scenario, the use of chromium trioxide will continue after the expiry of the current relevant Authorisations, i.e. from 2027 till the end of 2052. The critical endpoints are lung and intestinal cancer. Lung cancer is an effect caused by inhalation exposure. Oral exposure is the main exposure route associated with intestinal cancer.

In December 2013, RAC agreed lifetime mortality risk estimates associated with carcinogenicity for workers and members of the general population exposed to Cr(VI) substances[19]. It assumes a linear relationship for both lung and intestinal cancer.

These dose-response relationships are used in the calculations to derive the excess lifetime cancer risks for workers directly exposed to Cr(VI) in Rimex's production facility, other workers in the facility, and members of the general population (local and regional scale). As the excess cancer risk estimates apply to each exposed worker for a total working life of 40 years, they need to be adjusted to reflect

[19] ECHA (2013): Application for Authorisation: Establishing a reference dose response relationship for carcinogenicity of hexavalent chromium. Helsinki, 04 December 2013. RAC/27/2013/06 Rev. 1 (agreed at RAC-27).

exposures over the length of the review period. Exposures are thus treated as separable over time, meaning that annual risk is equivalent to 1/40 of the risk over 40 years of exposure. For members of the general population, excess cancer risk estimates apply for a lifetime of 70 years, meaning that annual risk is equivalent to a 1/70 of the risk of 70 years of exposure.

Table 4-8 indicates the range of excess cancer risks estimated for the total number of workers exposed across all of the different tasks.

Table 4-8: Excess cancer risks for exposed workers in Rimex's Enfield facility		
Number of workers exposed	**Excess cancer risks (task-related)**	**Excess cancer risks upper-end estimate**
25	$4.00E^{-03}$	$2.77x10^{-3}$ to $6.08x10^{-5}$
Source: CSR		

On the basis of the RCRs, excess cancer risks for local workers, and the local general population can be derived. They are summarised in the **Table 4-9** below.

Table 4-9: Excess cancer risks for humans via the environment	
Local scale	
General population (residents) and workers	
Inhalation	**Oral**
$2.9x10^{-02}$	$8x10^{-04}$
Source: CSR Regional exposure of the general population is not considered relevant by ECHA RAC/HSE	

4.3.1.3 Morbidity vs mortality

Excess cancer cases need to be split between fatal and nonfatal ones. To this end, estimates of fatality and survival rates associated with lung and colorectum[20] cancer cases were derived from the Cancer Today database, see **Table 4-10** below.

Table 4-10: Estimated incidence and mortality of cancers across the EU-27 and the UK, both males and females (in 2020)			
Type of cancer	**Cases**	**Deaths**	**Survivals**
Lung	370,310	293,811 (79%)	76,499 (21%)
Colorectum (intestinal)	393,547	177,787 (45%)	215,760 (55%)
Source: http://gco.iarc.fr/today/home (accessed on 20/02/2022) Note: Percentages have been rounded			

To calculate the number of additional non-fatal lung cancer cases, a ratio of deaths to survivals is applied to the number of additional fatal lung cancer cases, as shown below:

$$(0.21/0.79) \times \pi = \sigma$$

where π is the number of additional fatal lung cancer cases and σ is the number of additional non-fatal lung cancer cases.

Since the dose-response relationship gives the incidence (instead of cancer mortality), the figures from Cancer Today reported in **Table 4-10**:

[20] Colorectum is taken as a proxy for intestinal cancer cases.

above are applied to the estimates to calculate the number of fatal and non-fatal intestinal cancer cases.

- 0.45 x total number of cases (fatal + non-fatal) = δ
- 0.55 x total number of cases (fatal + non-fatal) = η

where, δ is the number of additional fatal intestinal cancer cases and η is the number of additional non-fatal intestinal cancer cases.

Note, however, that the estimated number of intestinal cases are found to be orders of magnitude lower than the number of lung cancer cases (for humans via the environment). Therefore, combined risk figures carried forward for valuation in the following sections.

4.3.2 Economic valuation of residual health risks

4.3.2.1 Economic cost estimates

In order to monetise human health impacts, a timeframe that goes from 2027 (inclusive of the end of 2027) to the end of 2052 (i.e., a 25-year review period) has been adopted and a 1.5% discount rate has been employed for calculating present values. It has been assumed that the levels of exposure to Cr(VI) for workers and members of the general population remain constant throughout the length of the review period, even though this is a very conservative assumption. In fact, downstream users will gradually reduce the amount of Cr(VI) consumed as the transition to the alternative proceeds. Combined with the investment in risk management measures put in place by the site to protect workers as a result of the conditions placed on continued use by the initial authorisations, this should ensure that excess lifetime cancer risks reduce over the review period.

The economic valuation of the health impacts takes into account two important welfare components, the costs associated with mortality and morbidity. The basis of our calculations is the study led by the Charles University in Prague[21] and undertaken for ECHA.

That study was critically reviewed by ECHA in 2016 and the results of that review have been the basis of the economic valuation performed here[22]. The values used are:

- Value of statistical life for the avoidance of a death by cancer: €3.5 million to €5 million (2012 prices); and
- Value of cancer morbidity: €0.41 million (2012 prices).

These figures have been converted to GBP[23], and then to 2024 values[24]. The updated figures can be seen below.

- Value of statistical life lower bound (mortality): £3.93 million (rounded);
- Value of statistical life upper bound (mortality): £5.62 million (rounded); and

[21] Alberini, A. and Ščasný, M. (2014) Stated - preference study to examine the economic value of benefits of avoiding selected adverse human health outcomes due to exposure to chemicals in the European Union - Part III: Carcinogens.

[22] ECHA (2016b) Valuing selected health impacts of chemicals. Available at: http://echa.europa.eu/contact

[23] https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/thap/mret

[24] https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-march-2025-spring-statement-quarterly-national-accounts

- Value of cancer morbidity: £0.50 million (rounded).

In addition to these valuations, for the purpose of quantifying human health impacts, consideration has also been given to annual medical treatment costs for morbidity. A range of studies were identified that provide estimates of the costs of medical treatment for patients surviving lung and intestinal cancer. These are summarised in .

Table 4-11: Alternative estimates of medical treatment costs

Study	Year for prices	Average direct costs in original units (per annum)	Direct costs in £ 2024
Lung cancer[25]			
Leal (2012)	2012	£9,071	£12,577.23
Braud et al (2003)	2001	€12,518	£17,356.60
Dedes et al (2004)	1999	CHF 20,102	£27,872.06
Intestinal cancer (colon, colorectal and rectal cancer taken as proxies)[26]			
Luo et al (2010)	2000 (assumed)	US$29,196	£26,699.10
Lang et al (2009)	2006	US$28,626	£21,537.17
York Health Economics Consortium (2007)	2004	£8,808	£12,212.57
York Health Economics Consortium (2007)	2004	£12,037	£16,689.68

The average cost across the lung cancer studies is £19,269 per annum (2024 prices). The average cost figures reported for intestinal cancer are based on figures produced for colon, rectal and colorectal cancer in the US and UK.

These average medical costs are annual figures and apply to survivors over the period of time that they continue to be treated. With respect to lung cancer morbidity cases, we have taken a percentage survival of 32% after one year since diagnosis, 10% after 5 years, 5% after 10 years[27]. With respect to intestinal cancer morbidity cases, we have taken a percentage survival of 76% after one year since diagnosis, 59% after five years, and 57% after 10 years. Based on these time periods, the PV of average future medical costs per lung cancer case is estimated at £26,458 in 2024 prices, using a 1.5% future discount rate. The Present Value (PV) of average future medical costs per intestinal cancer case is estimated at £147,866 in 2024 prices. It is noted that a large percentage of people survive intestinal cancer after a period of 10 years and any stream of health care costs incurred after that is not incorporated in our calculations. However, such costs are not likely to be relevant considering that those surviving after such a long period of time can either be considered as definitely cured or probably only in need of a small degree of medical attention.

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25 Leal, J., 2012. Lung cancer UK price tag eclipses the cost of any other cancer, presentation by Health Economics Research Centre, University of Oxford to the NCIR Cancer Conference, Wednesday, 7 November. s.l.:s.n. Braud, L. & al, 2003. Direct treatment costs for patients with lung cancer from first recurrence to death in France. Pharmacoeconomics, 21(9), pp. 671-679. Dedes, K. J. & al, 2004. Management and costs of treating lung cancer patients in a university hospital. Pharmacoeconomics, 22(7), pp. 435-444.

26 Luo, Z. & al, 2010. Colon cancer treatment costs for Medicare and dually eligible beneficiaries. Health Care Finance Review, 31(1), pp. 33-50. Lang, K. & al, 2009. Lifetime and Treatment-Phase Costs Associated with Colorectal Cancer: Evidence from SEER-Medicare Data. Clinical Gastroenterology and Hepatology, Volume 7, pp. 198-204. York Health Economics Consortium, 2007. Bowel Cancer Services: Costs and Benefits, Final Report to the Department of Health, April 2007, York: University of York.

27 These values are based on a study conducted by Cancer Research UK on adults aged 15-99 in England and Wales. https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/lung-cancer/survival.

An average of lung cancer and intestinal cancer treatment costs is used in the subsequent calculations.

The values of mortality and morbidity were multiplied by the estimated number of additional cancer cases, fatal and non-fatal, that can occur in the applied for use scenario.

Taking into account the latency period of cancer after exposure, a 10-year lag is applied[28]. Note that this is a conservative assumption because 10 years is based on occupational lung cancer exposure. A longer lag (i.e., discounted more heavily) is more relevant to other types of cancers (e.g., intestinal cancer) and exposure of general population via the environment. In short, the cancer cases occur after the 10-year latency period for 12 years corresponding to the applied for review period.

4.3.2.2 Predicted value of excess cancer cases with continued use: workers

Total excess cancer risk cases are based on the excess lifetime risk estimates derived in the CSR for the different worker contributing scenarios (WCS as presented in **Table 4-5**). These risk estimates reflect the additional safety measures that have been implemented due to the conditions placed on continued use by the initial authorisation decisions. The number of excess cancer cases is calculated by multiplying the number of workers assumed to be exposed in each task by the value of the excess cancer risk given above adjusted for the requested review periods, i.e., over 25 years. This value is then multiplied by the number of workers exposed in each WCS to calculate the total excess cancer cases arising from the continued use of chromium trioxide. **Table 4-12** provides a summary of the results across all WCS for workers.

Table 4-12: Number of excess lifetime cancer cases

WCS	Number of persons exposed	LUNG CANCER - Excess lifetime cancer risk	LUNG CANCER - Number of excess lifetime fatal cancer cases	LUNG CANCER - Number of excess lifetime non-fatal cancer cases
WCS 1	3	2.77E-03	8.31E-03	2.21E-03
WCS 2	5	3.75E-03	1.88E-02	4.98E-03
WCS 3	5	1.11E-04	5.55E-04	1.48E-04
WCS 4	2	1.25E-03	2.50E-03	6.65E-04
WCS 5	4	6.08E-05	2.43E-04	6.46E-05
WCS 6	2	1.10E-03	2.20E-03	5.85E-04
WCS 7	1	2.10E-05	2.10E-05	5.58E-06
	Years - Lifetime	**40**	**3.26E-02**	**8.66E-03**
	Years - Review period	**25**	**2.04E-02**	**5.41E-03**
	Years - Annual	**1**	**8.14E-04**	**2.17E-04**

Table 4-13 applies the economic value of the associated health impacts to these additional statistical cases of cancer to generate the total economic damage costs of the excess lung cancer cases.

[28] https://echa.europa.eu/documents/10162/17228/echa_review_wtp_en.pdf/dfc3f035-7aa8-4c7b-90ad-4f7d01b6e0bc

Table 4-13: Present value and annualised economic value of mortality and morbidity effects to workers (discounted over 25 years @3.5% per year, 10 year lag, figures rounded)				
	Lower bound costs		Upper bound costs	
	Mortality	Morbidity	Mortality	Morbidity
Total number of cases	2.04E-02	5.41E-03	2.04E-02	5.41E-03
Annual number of cases	8.14E-04	2.17E-04	8.14E-04	2.17E-04
Present Value (PV, in 2024 prices)	£877,915	£29,516	£1,254,164	£29,516
Total PV costs	£907,430		£1,283,679	
Total annualised cost	£55,057		£77,886	

4.3.2.3 Predicted value of excess cancer cases with continued use: humans via the environment

The total number of people exposed via the environment as given in **Table 4-7** is multiplied by the excess cancer risk estimates to calculate the total excess cancer cases arising under the Continued Use scenario. The results are given in **Table 4-14**. The basis for estimating the number of people exposed is given in section 4.4.3.2.

Table 4-14: Number of people in the general public exposed (local assessment)			
Exposed local population	Combined excess lifetime cancer risk	Number of excess lifetime fatal cancer cases	Number of excess lifetime non-fatal cancer cases
10,072	3.02E-04	3.04E+00	8.09E-01
Years - Lifetime cases	**70**	**3.04E+00**	**8.09E-01**
Years - Review period	**25**	**1.09E+00**	**2.89E-01**
Years - Annual	**1**	**4.35E-02**	**1.16E-02**

Due to the small number of cases estimated for intestinal cancer (orders of magnitude lower than the number of lung cancer cases for humans via the environment), all cases are assumed to have a 10-year latency period, and include medical costs considered for the average of lung and intestinal cancer (on top of value of statistical life and value of cancer morbidity). This has been done to err on the side of overestimation.

Table 4-15 applies the economic value of the associated health impacts to the additional statistical cases of cancer for humans via the environment to generate the total economic damage costs of the excess cancer cases.

Table 4-15: Present value and annualised economic value of mortality and morbidity effects HVE (discounted over 25 years @3.5% per year, 10 year lag, figures rounded)				
	Lower bound costs		Upper bound costs	
	Mortality	Morbidity	Mortality	Morbidity
Total number of cases	1.09E+00	2.89E-01	1.09E+00	2.89E-01
Annual number of cases	4.35E-02	1.16E-02	4.35E-02	1.16E-02
Present Value (PV, in 2024 prices)	£1,170,945	£40,913	£1,672,778	£42,709

Table 4-15: Present value and annualised economic value of mortality and morbidity effects HVE (discounted over 25 years @3.5% per year, 10 year lag, figures rounded)				
	Lower bound costs		Upper bound costs	
	Mortality	Morbidity	Mortality	Morbidity
Total PV costs	£1,211,857		£1,715,487	
Total annualised cost	£73,528		£104,086	

4.3.3 Human health impacts for workers at customers sites

Customers sites are not addressed in the CSR and they are not considered to be relevant in the context of the Authorisation.

4.3.4 Impacts on environmental compartments

4.3.4.1 Release of chromium trioxide

No environmental assessment from the release of chromium trioxide is carried out for the following reasons:

- Chromium trioxide has not been identified as a substance of very high concern in relation to their effects on organisms in the environment;
- Releases to environmental compartments from Rimex's activities are low as the whole process is characterised by wastewater reduction measures; and
- Cr(VI) from chromium trioxide is expected to reduce to Cr(III) under most environmental conditions, thus limiting any potential impact of Cr(VI) to the immediate vicinity of the source.

Although the continued use scenario will see ongoing release to the local environmental for several years, the use may result in a lower environmental impact than the impacts as part of the non-use scenario.

4.3.4.2 CO_2 emissions from PVD transport from around the world to the UK

A calculation of the costs of $_{CO2}$ emissions from PVD transportation from other countries (Asia, Europe and North America) is calculated in section 4.5.6.

4.3.5 Compilation of human health and environmental impacts

Human health impacts from the formulation activities are compiled in the table below.

Table 4-16: Combined assessment of health impacts to workers and general population (discounted over 25 years @3.5% per year, 10-year lag, figures rounded)				
	Lower bound costs		Upper bound costs	
	Mortality	Morbidity	Mortality	Morbidity
Total number of cases	1.11E+00	2.94E-01	1.11E+00	2.94E-01
Annual number of cases	4.43E-02	1.18E-02	4.43E-02	1.18E-02
Present Value (PV, in 2024 prices)	£2,048,859	£72,224	£2,926,942	£72,224
Total PV costs	£2,121,084		£2,999,166	
Total annualised cost	£128,695		£181,972	

4.4 Non-use scenario

4.4.1 Summary of the consequences of non-use

The most likely non-use scenario remains the same as the original application for authorisation, total closure of the Enfield site. Although Rimex have purchased equipment for production of PVD CSS, it is not deemed financially viable to operate this due to electricity costs. This renders the site not financially viable and will result in total closure. Rimex will continue to import PVD CSS. Downstream users will have to either import INCO CSS from sources outside the UK, or switch to PVD CSS (which is not considered to be a viable alternative).

4.4.2 Identification of plausible non-use scenarios

4.4.2.1 Likelihood and realism of "Non-use" scenario 1 – Closure of applicant's CSS production line

The applicant states in the case of a refused Authorisation, operation of the UK-based plant would not be viable. The INCO CSS plant would close in entirety, leading to loss of profits from the manufacture and sale of CSS, and unemployment of all employees at the site. Currently, Rimex are importing increasing amounts of PVD CSS from Asia, which would continue under this non-use scenario. It is likely that closure of the UK CSS site would lead to imported PVD CSS eventually replacing the chromate-based CSS.

4.4.2.2 Likelihood and realism of "Non-use" scenario 2 – Relocation of applicant's CSS production operations

Relocation of operations (potentially to Turkey or North Africa) would be a challenging task for a variety of reasons, including:

- Rimex is a SME, meaning that it would not be easy to undertake a project of such magnitude, considering the available skills of the current staff.
- CSS is a demanding product in terms of its manufacture, as it requires specific configuration and fine-tuning to start and maintain production. As a result, it needs stainless steel and chemicals of specific and consistent quality. Sourcing suitable stainless steel would be extremely difficult in such a country to the extent that it stops the project concept. This requires a reliable supply and a strong relationship with the supplier, supported by tonnage of supply for non-CSS stainless steel. It is feared that relocation outside the UK might affect

the reliability of sourcing the high quality grade of stainless steel currently required for the CSS manufacturing process and such a move would certainly affect the quality standards of production.

- The colouring plant cannot be installed separately from the rest of the plant. Ancillary operations including de-coiling, bead blasting, mirror polishing, satin polishing and patterning of stainless steel, would have to be accommodated in the new location. These are substantial and expensive pieces of equipment. Otherwise, Rimex would have to purchase already patterned and polished stainless steel sheets from local suppliers which is not possible outside Europe. As it stands, the stainless steel required for [redacted] #D, E [redacted]
- Along with the equipment, the expertise acquired in the years of operations would also have to be transported to the new location. Rimex has a relatively high employee retention rate, with the current average length of employment with the company being 12 years 3 months. This has contributed to the current employees' high level of knowledge of the process used and the products on offer. Therefore, key staff would also need to move to the new location. A successful relocation could not be guaranteed, so it is expected that some of the expertise within the current staff would be lost. Rimex does not believe it could find the necessary skills in other regions, at least in the short term.
- In addition to challenges around skills and expertise, re-locating outside of the UK may involve a variety of challenges, these challenges may include:
  - Language barriers
  - Legal and regulatory challenges, including securing permits, environmental clearances, operational licenses and our legal requirements
  - Labour law differences
  - Tax and corporate structuring
  - Sourcing from new local vendors and supply chain challenges
  - A lack of infrastructure reliability (power grid stability, road quality, and port efficiency)
  - Downtime between closing one site and opening another site
- Products manufactured outside the UK would attract additional shipping costs which would act as an import 'premium' for UK-based customers in particular, making the material less attractive vis-à-vis the competition. Increased lead times and loss of manufacturing control are additional problems that would arise from the longer distances between Rimex and its customers. Subsidiaries would also have to stock larger inventories, which is not a viable practice for supplying agents, forcing them to look for alternative suppliers for their CSS needs. There would also be additional costs to downstream users as a result of this.
- For goods imported into the EU there are tariff and quota safeguarding regulations (On 31 January 2019, the Commission adopted Implementing Regulation (EU) 2019/1591) in place since 2016 and from 2026 CBAM (Carbon Border Adjustment Mechanism) costs of €200-650/T depending on country of import that increase annually to 100% by 2034.
- It could be strongly argued that the UK is a better place to manage chemical risk and health and safety concerns than many places outside it, although it is acknowledged that in several non-UK countries worker protection standards could be comparable to UK ones.
- Finally, relocation would be a lengthy process which would mean that Rimex would not be able to place CSS on the market for several months, if not years. During this period customers would seek alternative sources of CSS. Once customers are lost, it is very difficult to attract them back, especially if the CSS made by Rimex outside the UK is not as competitively priced as it is now. It is also possible that cash flow problems would arise in setting up a new business to manufacture CSS outside the UK.

For the reasons above, Rimex would not be prepared to relocate its CSS-making operations and would strongly prefer closing the UK CSS production lines down. This "Non-use" Scenario would not be taken up by Rimex and is not considered realistic.

4.4.2.3 Changes to business model

Another option would be to change Rimex's business model; this would involve switching of the CSS business to importing and trading third-party-made PVD CSS from Asia. [redacted]

[redacted] #D, E [redacted]

[redacted]

[redacted]

As an overall conclusion, this "Non-use" Scenario is unrealistic as it would result in a very unprofitable business cycle. Such a situation would not be sustainable, as there appears to be no substantial expected benefits in the near future that could at least keep the plant running until an alternative manufacturing process is identified. As a result, Rimex would be forced to shut down all operations in the UK, thus transforming this "Non-use" Scenario into "Non-use" Scenario 1.

4.4.3 Conclusion on the most likely non-use scenario

In conclusion, the most likely non-use scenario would be closure of Rimex's Enfield site, with the continued importing of PVD CSS from outside of the UK. It will no longer be financially viable to maintain the Enfield site, and it is not cost effective for Rimex to manufacture PVD CSS. Customers will either import INCO CSS from another site in Europe, Asia or the USA, or switch to PVD CSS.

4.5 Societal costs associated with non-use

4.5.1 Economic impacts on applicants

Under the non-use scenario, Rimex will most likely close the Enfield site, whilst continuing to import PVD CSS from Asia. It is not clear whether their INCO customers will switch to Rimex imported PVD CSS, or find an alternative supplier of INCO CSS outside of the UK. As discussed in section 3, PVD is not a direct replacement to INCO. Mechanically, PVD CSS is not able to match the proven reliability and durability of INCO CSS in certain demanding applications. Due to this, it has been assumed that their INCO clients will look for an alternative supplier of INCO for the purposes of calculating producer surplus losses, rather than purchase PVD CSS from Rimex.

[29] https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7dt/mm23

Table 4-17 demonstrates the profits losses for 4 years and annualised, and calculated in line with SEAC guidance[30], these values do not take into account offsetting based on sale or scrap of equipment. The economic losses also do not consider any offsetting for rival firms. All of Rimex competitors are based in the EEA or Asia, there are no other UK based manufacturers of INCO CSS.

Table 4-17: Profit losses from 2027	
Year	**Lost EBITDA/Profit**
25 year profit losses	#E [redacted] <£9-13 million
4 year profit losses	[redacted] <£1.5-3 million
Annualised	[redacted] <£0.5 million
Source: Consultation EBITDA = Earnings Before Interest, Taxes, Depreciation, and Amortisation	

4.5.1.1 Decommissioning costs

Rimex state that there will be costs of around £500,000 for shutting down the Enfield plant. There would also be additional costs for land or warehousing for the PVD CSS that is imported, of around £500,000 per annum.

4.5.1.2 Offsetting profit losses

To offset profit losses and option could be to sale plant equipment, the action of Rimex closing may also benefit rival firms. As Rimex are the only manufacturer of INCO CSS in the UK, and no firms in the UK produce PVD CSS there is likely to be a limited ability for Rimex to sale plant equipment. As INCO CSS is not produced by any other companies in the UK and all PVD CSS would be imported from outside of the UK the profits losses would not be offset to another UK rival.

4.5.2 Economic impacts on the supply chain

As previously stated, it is unclear whether customers will switch to PVD CSS or import INCO CSS. INCO CSS would be the best choice for the technical performance reasons set out within this application. INCS CSS would have to be imported from Asia, Europe or America. However, within the EU the chromate restriction in Europe may impact the number of suppliers operating in the EU, this would potential force customers to import INCO CSS from Asia or America, alternatively customers may need to consider using INCO PVD in place of INCO CSS.

The closing of Rimex's site as part of the most likely non-use scenario may also impact Rimex's existing customers. Existing customers, especially any long-standing customers, would need to spend time identifying and sourcing alternative CSS for other companies. If alternative CSS cannot easily be sourced, these companies may need to consider re-designing their products which would involve the loss of time and resources.

4.5.3 Social impacts under non-use

The social costs expected under a non-use scenario, are the redundancies that would result from the closure of the Enfield site.

It is estimated that **29 jobs** will be lost across the UK, this would include those workers both working directly with the chromium trioxide, and additional workers as a result of total shutdown of sites. This

[30] https://echa.europa.eu/documents/10162/0/afa_seac_surplus-loss_seac-52_en.pdf/5e24c796-d6fa-d8cc-882c-df887c6cf6be?t=1633422139138

includes workers involved in subsequent steps in the process and related activities, such as laboratory workers and logistics.

4.5.3.1 Monetary Valuation of Job Losses

The method for estimating the social costs of unemployment follows that recommended by ECHA Dubourg (2016).[31] Costs of unemployment are calculated by adding up lost output which is equivalent to the pre-displacement gross salary throughout the period out of work, search costs, rehiring costs for employers and scarring effects, and deducting the value of leisure time.

Dubourg (2016) estimated different ratios of the social cost per job loss over the annual pre-displacement wage for European countries and the EU-28 as a whole that varies according to the mean duration of unemployment.

These figures are combined with the ratio of social costs per job loss provided in Dubourg (2016) and annual wages to calculate the social costs per lost job. Data were collected in the SEA questionnaire on the average salary for workers involved in the use of chromium trioxide. The average salary for these workers £37,000. The social cost of unemployment is £2,242,570 for the Enfield site. Note, that this does not take into account potential job losses throughout the supply chain.

4.5.4 Economic impacts on competitors

There are no other UK based manufacturers of INCO steel. In the EU, there are Steel Colour Spa based in Italy, and Inox Colour GmbH in Germany. It is not clear how these companies will be impacted as a result of the chromate restriction which is due to come into force in around 2029. Additionally, there are INCO CSS manufacturers in China, however their products are not often seen in Europe.

Due to the nature of the chromate restriction, it is not clear how competitors will be impacted in the non-use scenario. If Steel Colour and Inox-Colour continue manufacturing, some of Rimex customers may move to other European suppliers of INCO CSS. Other customers may choose to import Chinese INCO CSS or move to PVD alternatives.

4.5.5 Wider socio-economic impacts

As indicated previously, the closing of the site may impact Rimex's existing customers which will have knock on impacts for these companies that may have to source alternative CSS or completely different materials from other companies. Having to source alternative CSS may come at additional expense or extended lead times which would negatively impact these companies. Having to switch to an alternative material may come with negative performance impacts, this may also need the companies to spend time and resources on re-designing their products.

These impacts may involve negative spillover impacts across a range of sectors and broadly across most of regional economies of the UK where Rimex's customers are based and where CSS is used.

These impacts have not been quantified within this application. Although Rimex are aware of several well-known examples of where Rimex INCO CSS is used (see Annex 2 for some examples), Rimex does not always know where INCO CSS is used.

[31] Dubourg, R (2016): Valuing the social costs of job losses in applications for authorisation. Available at: https://echa.europa.eu/documents/10162/13555/unemployment_report_en.pdf/e0e5b4c2-66e9-4bb8-b125-29a460720554

The granting of this application will also help support Rimex's business confidence in moving ahead with investments including the installation of each new INCO CSS production line at a cost of around £750k-£1.0m. The service life of such production lines is around 25 year, this was noted by ECHA as part of the assessment of Rimex's original Authorisation application.

The granting of the application also aligns more broadly with new UK Government policies around regulators and regulation support growth[32] and announcements around the UK's Industrial Strategy[33] which include support for the UK manufacturing, steel and construction sectors where Rimex are part of these supply chains. The rejection of the application would mean the UK is even more reliant on overseas companies which may contribute to a larger trade deficit (a negative trade balance) and companies in these supply chains may be negatively impacted by longer lead times, supply chain disruption, tariffs and currency fluctuations.

4.5.6 Health and Environmental impacts

No direct human health or environmental health impacts are expected under the non-use scenario as the use of the chromates would cease after the expiry date of the current Authorisation.

However, a refused Authorisation for the use of chromium trioxide in INCO CSS would result in a gap in the market of an estimated #C (less than 1,000) t/y of INCO CSS. A significant quantity of CSS (INCO or PVD) would have to be imported from outside the UK. There are different market assumptions that could be made on the amount of Rimex INCO CSS intended for the UK market that would now have to be imported.

These imports are expected to have an additional impact on CO_2 emissions from directly from the transporting of CSS over greater distances. A report published by Cefic suggests that the average CO_2 emission factor for deep sea shipping is 8.4 g CO_2/tonne-km[34], whereas Climate Action Accelerator highlight higher emission estimates at 19 g CO_2/tonne-km for sea freight (and 1,054 g CO_2/tonne-km for air freight; 243 g CO_2/tonne-km for road transport and 16 g CO_2/tonne-km for rail)[35].

For a simple calculation of CO_2 emissions, a conservative estimate of 100 t/y that would need to be imported into the UK from abroad has been developed, it is also be assumed that one third of the total amount (ca. 33 tonnes of CSS of steel per year) would originate from Italy, one third would originate from China and one third from east coast USA and that these would arrive into the Port of Felixstowe/London Gateway.

Table 4-18 summarises the calculation of environmental externalities. The valuation of damages from CO_2 emissions is based on a value of £37 per tonne (as the cost of carbon), based on UK Government figures[36]. It is assumed that this price will remain constant from 2026 onward. Therefore, the

32 https://www.gov.uk/government/publications/a-new-approach-to-ensure-regulators-and-regulation-support-growth/new-approach-to-ensure-regulators-and-regulation-support-growth-html

33 https://assets.publishing.service.gov.uk/media/69256e16367485ea116a56de/industrial_strategy_policy_paper.pdf

34 McKinnon, A, Piecyk, M, 2018, "Measuring and Managing CO2 Emissions of European Chemical Transport", Available at: https://cefic.org/app/uploads/2018/12/MeasuringAndManagingCO2EmissionOfEuropeanTransport-McKinnon-24.01.2011-REPORT_TRANSPORT_AND_LOGISTICS.pdf

35 Climate Action Accelerator CO_2 emissions from freight and transport, available at: https://climateactionaccelerator.org/solutions/sea_freight/

36 Shadow value of carbon, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243825/background.pdf.

externalities of CO_2 emissions resulting from increased imports could tentatively be calculated as ca. £0.6 to 0.9 million per year.

Production of CSS in these quantities will not be lost completely, as demand is expected to remain. This means that CSS that is not produced by Rimex will be produced by some non-UK manufacturers. It can be argued that this would reduce GHG emissions in the UK, but climate change is considered a global issue. Thus, under the Non-use scenario there would be a net increase in non-internalised externalities associated with increased CO_2 emissions from the transport of CSS into the UK.

Table 4-18: Calculation of environmental externalities from increased steel imports into UK under the Non-use scenario

	Imports from China	Imports from USA	Imports from Italy	Sum Total
Grams CO_2 per tonne-km	8.4 – 19	8.4 – 19	243	-
CSS imports (t/y)	33	33	33	99
Distance from Port of Felixstowe/London Gateway (km)	17,950	5,800	1,320	-
Associated CO_2 emissions (t/y)	4,976 – 11,255	1,608 – 3,637	10,585	17,169
Cost per ton of CO2	37	37	37	-
Externalities of CO_2 emissions (£million/y)	**0.2 – 0.4**	**0.1**	**0.4**	**0.6 – 0.9**
Externalities of CO2 emissions over the 9 year assessment period, 3.5% discount factor (£million)	**5.9 – 8.8**			
Externalities of CO2 emissions over the 4 year assessment period, 3.5% discount factor (£million)	**2.4 – 3.6**			

Source: Consultation with Rimex. Distances calculated at https://sea-distances.org/ (accessed on 1 March 2026).
1 nautical mile = 1.825 km
Note: figures are rounded

The values included in **Table 4-18** may also underestimate the associated CO_2 emission and costs. For example, in some situations air freight may be used (particularly for smaller CSS items), furthermore the estimate of ca. 100 tonnes of CSS imports is lower than Rimex's annual production of INCO CSS.

4.5.7 Compilation of socio-economic impacts

Table 4-19 demonstrates the total monetised impacts relating to the non-use of chromium trioxide in INCO CSS. The profit loss figures have been discounted at 3.5% over four years, as stated in SEAC guidance for no-SAGA[37] scenarios.

Table 4-19: Societal costs associated with non-use 2027 onwards

Description of major impacts	Monetised/quantitatively assessed/qualitatively assessed impacts
1. Monetised impacts	**£ Present Value @ 3.5% over 4 years**
Producer surplus loss due to ceasing the use applied for	#D, E (£1.5-3 million)
Relocation or closure costs	£1,000,000
Loss of residual value of capital[38]	Not monetised
Social cost of unemployment[16]	£2,242,570

[37] No suitable alternatives generally available.
[38] If profit losses have not been already accounted for.

Table 4-19: Societal costs associated with non-use 2027 onwards	
Description of major impacts	**Monetised/quantitatively assessed/qualitatively assessed impacts**
Spill-over impact on surplus of alternative producers[17]	Not monetised
Sum of monetised impacts	[redacted] (£5-7.5 million)
2. Additional quantitatively assessed impacts	**£ Present Value @ 3.5% over 4 years**
Externalities of CO_2 emissions	£2.4-3.6 million
3. Additional qualitatively assessed impacts	Disruption and other impacts for existing customers and supply chains from having to source CSS from alternative suppliers.

4.6 Combined impact assessment

Table 4-20 sets out a summary of the societal costs associated with the non-use scenario. Figures are provided as annualised values, with costs also presented as a present value (PV) over a 4-year period. Overall, the monetised impact of non-use can be estimated at [redacted] (£9-13 million).

Table 4-20: Societal costs of non-use and risks of continued use			
Societal costs of non-use		**Risks of continued use**	
Monetised impacts £ over 4 years	[redacted] (£5-7.5 million)	Monetised excess risks to directly and indirectly exposed workers £ over 25 years	£0.91 to 1. 28 million
Additional quantitatively assessed impacts: Externalities of CO_2 emissions (0.6 to 0.9 £million/y over 4 years)	£2.4-3.6 million	Monetised excess risks to the general population £ over 25 years	£1.21 to 1.72 million
Summary of societal costs of non-use	[redacted] (£9-13 million)	**Summary of risks of continued use**	£2.12 to 3.00 million
Notes: 1. Annualised to a typical year based on the time horizon used in the analysis. 2. Per average year during the time horizon used in the analysis.			

4.7 Sensitivity analysis

In the accompanying spreadsheet of SEA calculations, a sensitivity analysis was performed of different CO_2 emission scenarios using different forms of transportation and import quantities. All of the scenarios involve significantly higher CO_2 emissions. The figures used in **Table 4-19** demonstrate a reasonably conservative estimate of CO_2 emissions and costs.

4.8 Information to support for the review period

4.8.1 Introduction

In a 2013 document, the ECHA Committees outlined the criteria and considerations which could lead to a recommendation of a long review period (12 years) (ECHA, 2013):

1. The applicant's investment cycle is demonstrably very long (i.e. the production is capital intensive) making it technically and economically meaningful to substitute only when a major investment or refurbishment takes place.

2. The costs of using the alternatives are very high and very unlikely to change in the next decade as technical progress (as demonstrated in the application) is unlikely to bring any change. For example, this could be the case where a substance is used in very low tonnages for an essential use and the costs for developing an alternative are not justified by the commercial value.

3. The applicant can demonstrate that research and development efforts already made, or just started, did not lead to the development of an alternative that could be available within the normal review period.

4. The possible alternatives would require specific legislative measures under the relevant legislative area in order to ensure safety of use (including acquiring the necessary certificates for using the alternative).

5. The remaining risks are low and the socio-economic benefits are high, and there is clear evidence that this situation is not likely to change in the next decade.

In the context of this application, the applicant has demonstrated that research and development efforts have already been made but these did not lead to the development of an alternative than can be implemented successfully in the normal review period, criterion 3. Furthermore, internal OEM certification requirements and several offshore health and safety requirements are in place to protect the health and safety of workers and reduce the risks of incidents causing environmental harm. Using an unproven alternative that has not been fully tested creates risks which are similar to the requirements under criterion 4 above.

Further discussion was held at the 25th Meeting of Competent Authorities for REACH and CLP (CARACAL) of 15 November 2017. A document endorsed by CARACAL suggests that, "*in order to consider a review period longer than 12 years, in addition to the criteria for a 12-year review period established in the document "Setting the review period when RAC and SEAC give opinions on an application for authorisation", two additional conditions should jointly be met*:

6. As evaluated by the RAC, the risk assessment for the use concerned should not contain any deficiencies or significant uncertainties related to the exposure to humans (directly or via the environment) or to the emissions to the environment that would have led the RAC to recommend additional conditions for the authorisation. In the case of applications for threshold substances, the appropriateness and effectiveness of the applied risk management measures and operational conditions should clearly demonstrate that risks are adequately controlled, and that the risk characterisation ratio is below the value of one. For applications for non-threshold substances, the applied risk management measures and operational conditions should be appropriate and effective in limiting the risks and it should be clearly demonstrated that the level of excess lifetime cancer risk is below $1x10^{-5}$ for workers and $1x10^{-6}$ for the general population. For substances for which the risk cannot be quantified, a review period longer than 12 years should normally not be considered, due to the uncertainties relating to the assessment of the risk.

7. As evaluated by the SEAC, the analysis of alternatives and the third party consultation on alternatives should demonstrate without any significant uncertainties that there are no suitable alternatives for any of the utilisations under the scope of the use applied for and that

it is highly unlikely that suitable alternatives will be available and can be implemented for the use concerned within a given period (that is longer than 12 years)" (CARACAL, 2017).

As far as the second criterion above is concerned, the same document provides some relevant examples, one of which (Example (d)) reads as follows:

> "(…) *the use of the substance has been authorised in accordance with other EU legislation (e.g. marketing authorisation, certification, type-approval), the substance being specifically referred to in the authorisation/certification granted and substitution, including the time needed for modification of the authorisation/certification/type-approval, would not be feasible within 12 years and would involve costs that would jeopardise the operations with regard to the use of the substance*".

4.8.2 Criterion 1: Demonstrably Long Investment Cycle

The applicant operates within a capital-intensive manufacturing environment, where equipment and infrastructure require significant upfront investment and are designed for long-term use, often spanning decades. Since the inception of commercial CSS manufacturing in 1973, the applicant has been utilising the same stainless steel plant although it has effectively been replaced piecemeal over that time through repairs, replacement and improvement. Standing the test of time, with improved upon iterations, the manufacturing capability proves excellence in providing desired properties of INCO CSS for external structure applications.

The CSS industry is driven by economic, and technological impacts. Long design and investment cycles, as well as very long in-service time of their products are required to meet high safety standards and a key criterion for several customers is reliability. Rimex note that they are expecting to utilise INCO CSS up until the extra-long review period ends, with which they hope to have made progress to discontinue or switch to an alternative by then. Given the long investment horizon, substituting chromium trioxide for an alternative process such as PVD would not be appropriate for several end uses and it would also requires system-wide redesigns. [redacted] #D, E [redacted]

Technologically, PVD CSS proves to be an energy intensive process- far outweighing INCO manufacturing processes. On top of the energy intensive nature, output production rate is inferior to that of INCO processes. That is, more than six PVD CSS lines would match the production rate of three INCO CSS line. The level of existing investment has been costly especially as the increase in energy prices have massively inflated the operating costs of PVD CSS production. It is understood that the timeline for starting production is not within the foreseeable future.

Identified potential alternatives such as sulphuric acid, KOH, and other transition metal compounds have proved to have some positive impact on considering a substitution method, however, there is overwhelming consensus that more research is needed, with little to no evidence of translating these alternatives to an industrial scale. Therefore, constructing a CSS manufacturing plant with these "potential alternatives", without further efforts in R&D would not make business or economic sense.

As captured in the ECHA's Final Opinion as part of the original application, Rimex's investment cycle is very long and newly installed lifetimes of manufacturing lines are typically a minimum of 20 years.

As such, a review period of at least 12 years (25 years requested) is warranted and requested for the highly complex systems used in the manufacturing of CSS with properties akin to INCO CSS.

A 25-year review period in itself may not be sufficient for the applicant to develop a suitable alternative/ alternative process and develop industrial processes. A 25-year review period will enable the implementation of the significant (additional) investment in new lines, investment into further R&D, qualification and certification of design/drawing changes and industrialisation required.

4.8.3 Criterion 2: Cost of moving to substitutes

The longstanding use of Cr(VI) within the CSS industry over many years have allowed for multiple iterations in development of procedure. Would it be sensible to assume that the steadfast technology and technique of the INCO CSS process could be replicated by a fraction of the time taken in research, development, and integration of an alternative substance and/or process? One of many factors that have enabled the sustainability of the INCO process is the viability of the bottom line. Namely, that the revenue generated outweighs the administrative, and operational costs sufficiently to allow a business to function healthily. Conversely, as will be clear, alternatives outlined in this RR prove to be inferior in economic and technical factors.

The costs of implementing a new INCO CSS production line is ~£1.5m, which is required to meet high safety standards. Although seemingly expensive, reliability ensues, with which these production lines enable the ability to meet product user targets. Therefore, the integration of alternative processes could involve the complete redesign and construction of a new CSS production line. [redacted] #D, E [redacted] Energy costs prove to be a key driving factor for problems associated with substitution, at the cost of expending large amounts for the construction of the plant (in the region of £900k). This is backed by commentary from industry representatives.[39, 40] The energy intensive process of PVD CSS consumes roughly 562 MWh/year in comparison to the lower figure of 467 MWh/year for INCO CSS. Additionally, PVD CSS manufacturing in the UK proved to be a slower process than that of INCO CSS; 53,172 m^2 of stainless steel sheets were produced in a year. Although no defined quantity was provided for PVD CSS, the longer process in manufacturing contrasted with INCO CSS inherently supports the rational of a costlier operation.

Similarly, the integration of alternative substances to undertake the replacement for INCO CSS processes must be thoroughly planned, otherwise faults in the manufacturing process would lead to incurrence of unnecessary costs. Ultimately particular care should be taken to enforce reliability and safety of operations. Reliability and quality involves appropriate comparisons that lead to physical properties, between any alternative and INCO CSS, unbecoming of dissimilarity. Another alternative to the restriction, would be to relocate the production of INCO CSS, however the applicant states a costly figure of ~£20 million.

These technical hurdles are a fundamental reason why the INCO CSS industry requests a review period of 25 years.

4.8.4 Criteria 3 & 7: Results of R&D on alternatives and availability of alternatives over the longer term

Research into the substitution of chromium trioxide has been ongoing in relatively short amounts, stimulated by the prior AfA and sponsored by the applicant. However, research efforts have come

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[39] UK industry paying the highest price for energy, found here: https://www.thetimes.com/article/d7213155-72c9-4a40-85df-b285bc2bfb4c?shareToken=f799ac5ea7fd38685201e53c0d38fb7e

[40] The UK Department for Energy Security & Net Zero – Energy Prices International Comparisons, suggest that electrical energy cost in the UK from 2020-2023 are around 52.7% higher relative to the EU27.

short of sought after expectations which have halted progress in finding a suitable alternative. R&D efforts have now been setback to the initial stages of identifying, and conducting field research.

As was noted in previous sections of the RR, the applicant has previously sponsored two PhD's. The first PhD took place from October 2013 and ended October 2016. They explored 'The Electrochemical Colouring of Austenitic Stainless Steel in Chromic Acid Free Solutions' with focus on two objectives: To examine suitable alternative oxidising media to colour stainless steel; And to develop a suitable alternative colouring process route that does not involve the use of chromium trioxide, or any other material under regulatory threat. Whilst the second PhD occurring between October 2016 and September 2019, focussed on a more extensive set of objectives: To fully understand the colouring processes for austenitic stainless steels in molybdate containing solutions; To examine suitable oxidising media to help to maximise the adhesion of colour finishes on stainless steels from molybdate solutions; To investigate any other colouring systems using environmentally benign chemical constituents, for example trivalent chromium-based; To investigate the preliminary scale up of the most successful replacement systems. Unfortunately, over 7 years of research, and total costs of up to [redacted], none of the processes investigated in either PhD project were able to match the aesthetic quality, mechanical performance, and environmental benefits of the INCO process using chromium trioxide.

The overall conclusion from the two research projects, was stated as that all viable options have been exhausted for the time being. Therefore, this poses a fundamental reason why the INCO CSS industry requests a review period of at least 25 years, to accommodate for further challenges as part of the research process.

4.8.5 Criterion 4: Legislative measures for alternatives

This criterion has not been assessed as part of this application, as set out previously in the application of stakeholders within the supply chain, including those that are operating in sectors such as the construction sector may need to ensure that their end products are fulfilling key health & safety and regulatory requirements. Some of these sectors and uses may involve certification requirements.

4.8.6 Criterion 5 & 6: Comparison of socio-economic benefits and risks to the environment and effective control of the remaining risks

As part of this application the cost benefit ratios have been shown to be positive, this includes the situation where the costs to society as part of continued use and 25 year review period are compared to benefits of continued use for Rimex over a four year period.

As indicated in the conclusion Rimex are committed to make investment in their Enfield site (or another site if that becomes relevant), these investments to the manufacturing lines are expected involve the implemented of new technologies and other improvements that will have the benefit of reducing the risk of occupational and environmental exposure.

5 CONCLUSION

Rimex have a clear vision where INCO CSS has a future and remains important to the future for the company. INCO CSS remains a profitable product for Rimex and its sister companies and is needed by customers from several sector types and customers both in the UK and around the world.

Rimex believe one of their EU competitors, Inox Color GmbH has been in a form of receivership for 24 months, and it is presumed that they will close their site and its capacity for INCO CSS will become available. It is unclear whether another competitor, Steel Colour spa, are covered by an Authorisation and who they manage the EU chromates REACH Restriction when it enters into force. This capacity may become availability at a later date.

Rimex recognise that as part of making this application a positive outcome would provide business confidence in making significant investments at the Enfield site, these investments would include:

- Upgrading colour lines. This would include new gantry's, cranes, and tanks where needed. From there reviewing what was necessary for the youngest colour line.
- Adding a new electric polishing line which would be a modern design and feature new technologies and / or upgrading the current electro-polishing line.
- The installation of larger tanks across these lines.

The upgrades and investments which will feature a variety of new technologies are expected to result in a broad range of improvements that will lead to a reduction in occupational exposure risks.

An extra-long 25-year review period will help to provide the justification for these investments and the inclusion of feasibility studies and implementing these actions could be considered for inclusion as conditions within the Authorisation decisions.

Rimex have previously shown how they have undertaken significant investments, including in investments that have not always delivered the desired outcomes. [redacted] #D, E [redacted]

A range of techniques were used in this Authorisation Review Reprot as part of the identification of potential alternatives. R&D was undertaken by the applicant through the sponsorship of two PhD students, both studies focussed on differing techniques in SS colouring. Data taken and utilised from a parent AfA prior to this, aided in identification of potential alternative colouring techniques such as PVD. From the identification of PVD, consultation and R&D initiatives were conducted with stainless steel coating manufacturers in China and Taiwan, as well as PVD equipment manufacturers. The majority of potential alternatives to Cr(VI) in CSS were reported in the parent AfA as being realistic or the most promising but unrealistic in the short- to medium-term.

A shortlist of potential alternatives and their feasibility can be found in **Table 3-4**. However, from vast sources of literature, the applicant of the parent AfA concluded that much more investigatory work should be done regarding film properties with more proof needed on an industrial scale. As part of the second PhD additional R&D was conducted but an alternative was not identified.

In recent years market trends have had a negative impact on all wider demands on steel, not just INCO CSS, however Rimex are optimistic that demands will increase again following recent conflicts, post-COVID economic downturn, and some economic instabilities. Companies leaving the INCO CSS market may also result in additional demands for Rimex's INCO CSS.

Efforts were made in Authorisation Review Report to follow criteria and considerations outlined by the ECHA Committees which would lead to a recommendation of a long review period. The criteria that posed no significance was whether possible alternatives would require specific legislative measures under the relevant legislative area to ensure safety of use. A demonstrably long investment cycle was explored, it revealed that a 12-year review period would perhaps not be sufficient for the applicant to develop a suitable alternative/alternative industrial process. The cost of moving to substitutes was next explored with which the complexities involved in the process was outlined, such as energy costs, and technical challenges. The planning involved for the integration of alternative substances must be thoroughly planned, and thus conclusively points to a review period of 25 years. The results of R&D on alternatives and availability of alternatives over the longer term outlined previous attempts at finding an alternative. The costly process with the lack of conclusive and useful yield has ultimately exhausted all viable options for the time being. Further contributing to the reasons for an extra-long review period.

5.1 Comparison of the benefits and risk

The requested review period for the continued use of Cr(VI) is 25 years for use in the UK. The most likely non-use scenario would be for Rimex to close the Enfield site, whilst continuing to import PVD CSS from Asia. It has been assumed that their INCO clients will look for an alternative supplier of INCO rather than purchase PVD CSS from Rimex. The closure of the Enfield site will result in 29 job losses.

Overall, net benefits of approximately £125,000 to £179,000 (annualised social costs/annualised risks to human health, 3.5% discount) can be estimated for the continued use scenario. These figures capture lost profits to the applicant and social costs of unemployment. The ratios of the total costs of non-Authorisation (i.e. the benefits of continued use) to the residual risks to human health are greater than 1 #G [redacted].

It should be noted that the costs benefit ratio considers the cost to society as part of continued use over the 25 year review period and it compares these to benefits of continued use for Rimex over a four year period.

5.2 Substitution effort taken by the applicant if an authorisation is granted

As indicated above, Rimex’s immediate efforts will be to upgrade their manufacturing lines while significant R&D efforts can be demonstrated by the two Rimex funded PhD. An extra long review period will provide Rimex great business confidence and significantly more time to consider the most appropriate R&D approaches to take in the future.

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ANNEX 1 – Instructions on how to document confidential and public information

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]

Table A1-1: Justifications for confidentiality claims			
Reference type	**Commercial Interest**	**Potential Harm**	**Limitation to Validity of Claim**
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table A1-1: Justifications for confidentiality claims			
Reference type	**Commercial Interest**	**Potential Harm**	**Limitation to Validity of Claim**
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		[redacted]

Table A1-1: Justifications for confidentiality claims			
Reference type	**Commercial Interest**	**Potential Harm**	**Limitation to Validity of Claim**
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

ANNEX 2 – Additional examples of the Rimex INCO CSS range

In the table below specific examples of INCO CSS produced by Rimex can be found, in addition to these examples further examples can be found on Rimex's website in several places, including: https://www.rimexmetals.com/projects/architecture

Table A2-1: Projects using Rimex INCO CSS		
Project	**Product**	**Description of Project**
Sherman Theatre, Cardiff	316 Champagne Pegasus.	Originally opened in 1973, the theatre underwent a revamp and external facelift with the installation of overlapping shingles in the Rimex 316 Champagne Pegasus finish. Around 1800 m2 of product was used with the majority installed as shingles in 0.8mm thickness and a smaller quantity in 1.5mm installed in other areas around the wider project.
Dalton Nuclear Institute Cumbrian Facility	316 grade 0.8mm ColourTex® Black Mirror.	An excellent example of composite cladding that proves that thin gauge stainless steel can have a very flat appearance when correctly installed. In this case, Rimex ColourTex® Black Mirror was bonded to honeycomb backing over its whole surface and fixed back to the carrier system to create the desired effect. The different panel sizes combine with the reflective quality and slight tonal diversity of the ColourTex® process, bringing added visual interest to a dramatic structure.
Aleja Shopping Centre, Slovenia	Granex™ M1A finish in ColourTex® Bronze, Champagne and Rosy Gold	The Aleja shopping centre in Ljubljana is a commercial centre and stand-out architectural project in the area. 6500m2 of assorted Rimex finishes in 316 grade 0.6mm stainless steel was used on the glass and stainless steel façade, with Rimex products also utilised in the interior for vertical surface cladding to walls and balconies through the installation of metal shingles.
Bentley Cars, United Kingdom	ColourTex® Black Mirror	Contributing to one of the most iconic motoring manufacturer's vehicles is testament to the esteem of stainless steel. Aesthetics and durability have combined to create the front grille and door trims to the Bentley Mulsanne.
Wales Millennium Centre, Cardiff	316 Bronze 6WL, 316 Bronze Canvas, 304 Bronze Pearl.	The façade is a mixture of 0.8mm Bronze 6WL in 316 grade material face fixed to the roof and front elevation with Bronze Canvas used to the side elevations of the building. Whilst at the time of the opening, debate was provoked by the project as to what the material used was, it is ColourTex® stainless steel. This, being the result of a light interference effect, changes in appearance with ambient light conditions and angle of inspection so it can appear very dark bronze or a light sandy tone at different times. The theme is carried inside with 304 Bronze Pearl being used to vertical surfaces and ceiling areas. This building, which is located in a bay, was opened in 2004 and remains a great reference for Rimex and stainless steel.
Waitemata Railway Station, New Zealand	304 ColourTex® Blue Quilted, ColourTex® Blue Pearl	The transport hub of Auckland and located in the centre of the Central Business District, Waitemata Railway Station, formerly known as Britomart, has seen a large amount of stainless steel being used throughout.

		From wall and column cladding to fire doors, stainless steel is a versatile yet durable choice of material in high traffic areas.
Commercial Kitchen Ovens	304 ColourTex® Black Mirror.	These commercial ovens have been created from a black mirrored stainless steel, adding an additional dimension of aesthetics to a conventional appliance. The doors and control panels have been created from a 1.5mm black stainless steel.
Elizabeth Line, London	ColourTex® Black Granex™ M1A	Opening in May 2022, the year of the Queen's Platinum Jubilee, the Elizabeth Line is the result of the biggest infrastructure project in a generation, connecting Central London with Reading in the west, and Shenfield in the east. Rimex supplied approximately 30 tonnes of 316 grade stainless steel for the regeneration of Whitechapel Station alone; this material was a mixture of 1.5mm and 2.0mm in Granex™ C1A, M1A, 2WL and Inco Black Granex™ M1A finishes. These finishes were then utilised across ticket hall areas, concourses, stairwells, lifts, columns, and kick plates to fire doors, adopting a variety of fabrication techniques throughout the station. In the right fabricator's hands, the possibilities are limitless. Stainless steel is a very durable material, even when used in high traffic areas.

ANNEX 3 – Results of previous screening of potential alternatives to chromium trioxide

Table A3-1: Results of screening of potential alternatives to chromium trioxide						
#	Alternative	Relevant process step	Commercialisation	Technical feasibility	Suitability	Overall
Alternative substances						
1a	Permanganate salts	Colouring	Unproven	Infeasible	Unsuitable	**Eliminated as unrealistic and unsuitable**
1b		Colouring	Unproven			
2	Pentavalent Vanadium compounds	Colouring	Unproven; issues with substance availability	Infeasible	Suitable	**Eliminated as unrealistic**
3	Sulphuric acid (H_2SO_4)	Colouring (hardening unclear)	Unproven	Infeasible	Suitable	Promising but unavailable on industrial scale, thus eliminated
4	Phosphoric acid (H_3PO_4)	Colouring	Unproven and unrealistic, given the age of the source	Infeasible	Suitable	**Eliminated as unrealistic**
5	Potassium hydroxide (KOH)	Colouring	Unproven	Potentially feasible	Suitable	Promising but unavailable on industrial scale, thus eliminated
6	Sodium hydroxide (NaOH) & Sodium nitrate ($NaNO_3$)	Colouring	Unproven and unrealistic, given the age of the source	Infeasible	Suitable	**Eliminated as unrealistic**
7	Ionic liquids (KNO_3 & $NaNO_3$)	Colouring	Unproven	Infeasible	Suitable	**Eliminated as unrealistic**
8	Molybdates	Colouring	Unproven	Potentially feasible	Suitable	Promising but unavailable on industrial scale, thus eliminated

Table A3-1: Results of screening of potential alternatives to chromium trioxide

#	Alternative	Relevant process step	Commercialisation	Technical feasibility	Suitability	Overall
Alternative technologies						
9	Physical Vapour Deposition (titanium sputtering)	Colouring and hardening	Commercially proven	Feasible but with disadvantages	Suitable	Retained for detailed assessment
10	Heat colouring (heat tint/thermal colouring)	Colouring	Unproven on industrial level	Infeasible	Suitable	**Eliminated as unrealistic**
11	Laser induced colour marking	Colouring	Unrealistic for Rimex's use	Infeasible	Suitable	**Eliminated as unrealistic**
12	Colouring with titanium complex fluorides and zirconium complex fluorides	Colouring	Unproven	Infeasible	Suitable	**Eliminated as unrealistic**
13	Zirconisation™	Colouring	Unproven	Infeasible	Suitable	**Eliminated as unrealistic**
14	Metallic coatings	Colouring	Available (but possibly not relevant)	Infeasible	Suitable	**Eliminated as unrealistic**
15	Thermal hardening	Hardening	Unproven on industrial level	Infeasible	Suitable	Promising but unavailable on industrial scale, thus eliminated

ANNEX 4 – New orders in the construction industry

The following two figures are taken from the Office for National Statistics. They are based on Office for National Statistics and Barbour ABI data on new Orders for construction: volume seasonally adjusted index numbers, by main contractor, by sector, constant prices. The information is based on information for the Construction Industry of Great Britain, this includes.

- New housing public
- New housing private
- Other new work infrastructure
- Other new work excluding infrastructure
- Private industrial
- Private commercial

The two figures show data for 2010 to the present. The figures show that coming out of the global financial crisis of 2008 (not shown in the figures), construction demand started to return and grew annually from 2011 to 2017, however, since 2017 construction output has significantly been impacted by years of increasing and decreasing demand. The levels have not yet returned to the levels of demand from 10 years ago but there are recent positive trends following the COVID pandemic.

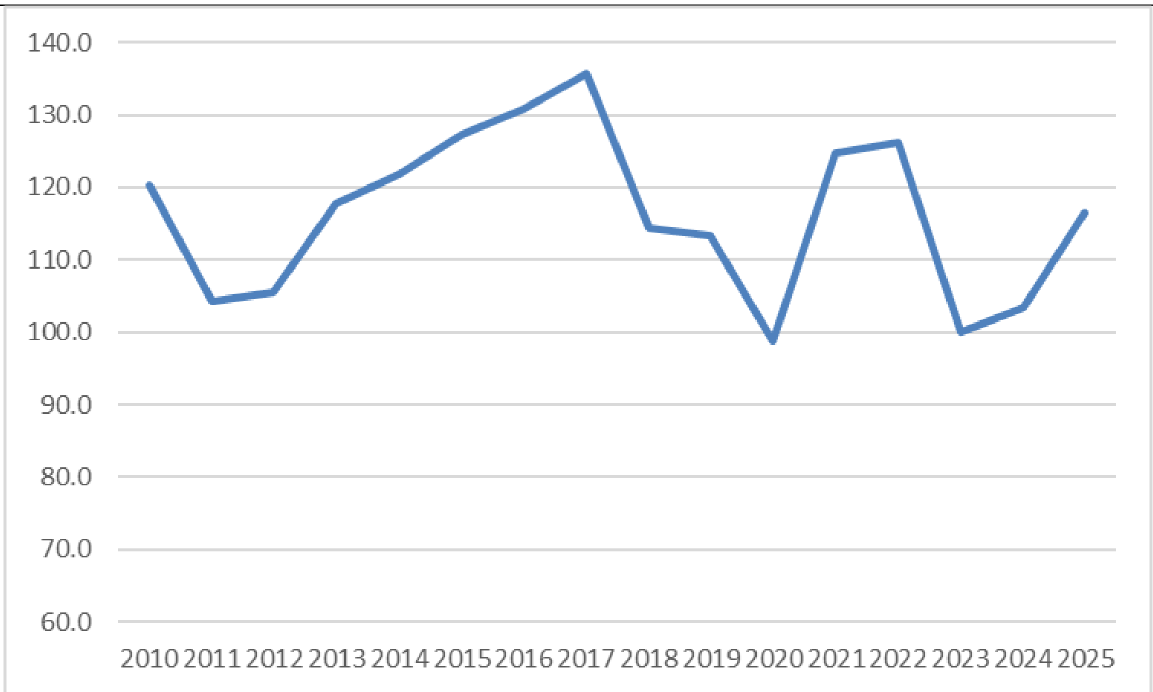

Figure A4-1: All new construction work from 2010 to 2025

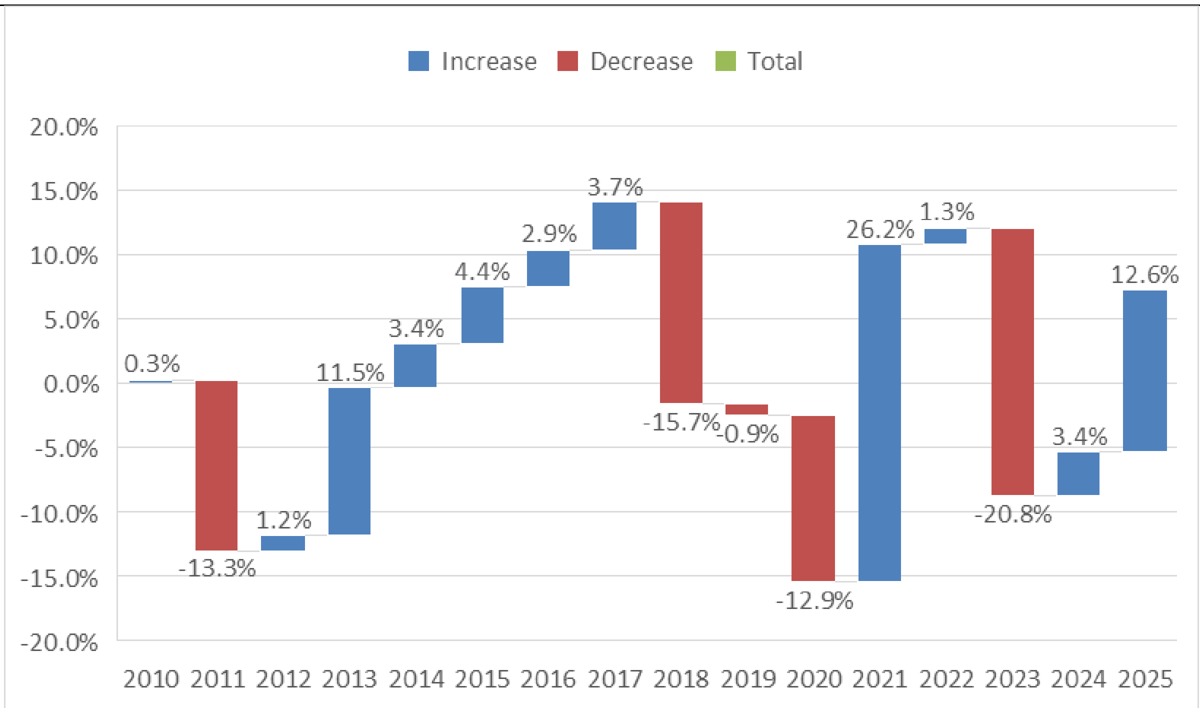

Figure A4-2: Period on period growths (%) of all construction work from 2010 to 2025

ANNEX 5 – [redacted]

[redacted] #D, E [redacted]

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[redacted]

[redacted]

Figure A5-3: [redacted]

[redacted]

APPENDICES

See separate confidential appendices.