ANALYSIS OF ALTERNATIVES

and

SOCIO-ECONOMIC ANALYSIS

Legal name of applicant(s):	Edbro Hydraulics Ltd I Holland Ltd Precision Products (UK) Ltd Riverside Gravure Ltd Rotometrics International Ltd Spline Gauges Ltd
Submitted by:	The Surface Engineering Association on behalf of the members of the Surface Engineering Association Chromium Trioxide Authorisation Consortium
Date:	21st March 2023
Substance:	Chromium Trioxide EC: 215-607-8 CAS: 1333-82-0
Use title:	Use of chromium trioxide for the hard (functional / engineering) chromium electroplating of engineering components as part of an in-house production facility with the purpose of creating a coating to meet specific performance characteristics.
Use number:	2

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4 – Socio-Economic Analysis

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LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
AoA	Analysis of Alternatives
BAuA	German Federal Institute for Occupational Safety & Health
CTAC	Chromium Trioxide Authorisation Consortium
ECHA	European Chemicals Agency
GDP	Gross Domestic Product
PVD	Physical Vapour Deposition
SEA	Socio-Economic Analysis or Surface Engineering Association
SVHC	Substance of Very High Concern

DECLARATION

We, the Applicants, are aware of the fact that further evidence might be requested by HSE / DEFRA 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 21st March 2023 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.

Signed on behalf of the Applicants by the Surface Engineering Association representing the members of the Surface Engineering Association Chromium Trioxide Authorisation Consortium

Signature.

Name. David Elliott
Position. Chief Executive
Date. 21st March 2023
Place. Birmingham, UK

1.SUMMARY

This Analysis of Alternatives and Socio-Economic Analysis relate to the application for authorisation for the continued use of chromium trioxide in hard chromium electroplating processes for components with specific technical performance requirements. Typical components are hydraulic pistons, cylinders and sealing rings, gravure printing components, rotary tooling, shafts and pump rotors, fire protection, components for the production of textiles and printing, press punches, tooling, dies and moulds. All the companies involved in this application carry out in-house hard chromium electroplating.

The document has been produced by a consortium of chromium electroplating companies with the assistance of the Surface Engineering Association and their sector consultants. Full details of the companies are provided in a separate spreadsheet.

The function of the chromium trioxide is to provide a metallic chromium electroplated coating, which is essentially inert, as per BS EN ISO 6158[1]. The chromium electroplating coating provides specific characteristics that include corrosion resistance, chemical resistance, wear / abrasion resistance, adhesion and heat resistance. In addition, the coating is fully recyclable and worn components can be reclaimed.
Hard chromium electroplating has been commercially available since the late 1920’s and the process has continued to be improved and developed. Much research and development has been undertaken to find alternatives to chromium electroplating using chromium trioxide and there are currently five particular technologies that could be considered as potential alternatives for this particular use. Trivalent hard chromium electroplating, thermal spraying processes, electroless nickel plating, Physical Vapour Deposition (PVD) and Nitro-Carburising.

However, when examining the specific performance requirements of the required coating, none of the potential alternatives were considered to be viable alternatives at the present time nor in foreseeable future. A review period of 12 years is therefore requested. Any further research and development of these 5 potential alternatives and any newly developed coatings will be regularly monitored to ensure that the reasons for rejecting these potential alternatives is still valid. This monitoring will be undertaken by members of the consortium, the Surface Engineering Association and other actors along the supply chain.

The application for authorisation by the Chromium Trioxide Authorisation Consortium (CTAC)[2] submitted to the European Chemicals Agency (ECHA), stated: As of today, no complete chromium trioxide free process, providing all the required properties to the surfaces of all articles in the scope of this application, is industrially available. This consortium included two of the largest suppliers in Europe of electroplating and surface engineering wet chemistry, clearly confirming the statements in the paragraph above.

1.1 Continued Use Scenario

The applicants will continue to use chromium trioxide under the ALARP[3] principles and, in conjunction with the Surface Engineering Association, will continue to monitor any R&D activity and development of potential alternatives. The applicants will continue to support UK manufacturing and contribute to the UK Government’s Growth Agenda and net-zero targets.

1.2 Most Likely Non-Use Scenario

The most likely scenario if the application for authorisation is not granted is widespread business closures, supply chain disruption and relocation of manufacturing facilities outside of the UK.

1.3 Societal Costs on Non-Use

The societal costs resulting from non-use is £469.76M over a 6-year period, £15.138M of that resulting from unemployment and lost wages.

1.4 Residual Risks

When considering the worst-case scenario, the excess lung cancer risk is 0.014 (due to the number of workers involved and the use of very conservative exposure data) and by the continued use of biological monitoring, all routes of exposure can be assessed and the principles of ALARP – as low as reasonably practicable – will be continued at all sites.

1.5 Conclusion

The societal costs of not granting this authorisation far outweigh the residual risks from the continued use of chromium trioxide by these applicants.

2. AIMS AND SCOPE

This application for authorisation covers the use of chromium trioxide in order to produce an electroplated coating of metallic chromium which provides specific properties and performance characteristics. This SEA / AoA is part of the application for authorisation dossier produced by the consortium members.

The aim of the AoA is to demonstrate that no suitable alternatives to the use of chromium trioxide is currently available for this specific use.

The aim of the SEA is to demonstrate that the benefits of the continued use of chromium trioxide, for this specific use, far outweigh any potential risks to human health and / or the environment.

The scope covers the companies carrying out the chromium trioxide using process and their customers and details the societal implications of a refusal to grant an authorisation for the continued use of chromium trioxide for this specific use.

The companies using chromium trioxide are all based in the UK, so provide direct employment, generate tax revenues and preserve specialist engineering skills.

3. ANALYSIS OF ALTERNATIVES

3.1. SVHC use applied for

Use of chromium trioxide for the hard chromium electroplating of various components with technical performance requirements, such as hydraulic pistons, cylinders and sealing rings, gravure printing components, rotary tooling, shafts and pump rotors, fire protection, components for the production of textiles and printing, press punches, tooling, dies and moulds with the purpose of creating a coating to provide specific performance characteristics

3.1.1. Description of the function(s) of the Annex XIV substance and performance requirements of associated products

Chromium trioxide is used to produce an electroplated metallic chromium coating specifically for engineering / functional purposes:

For this specific use, it is part of an integrated process which consists of a number subsequential process steps as shown below:

A – Pre-treatment processes

These processes clean the surface of the component to ensure that the surface is clean and ready to accept the electroplating processes. These processes can also remove the electroplating from previously coated components. They also can include polishing processes in order to obtain a mirror-like finish.

B – Electroplating processes

This the hard chromium electroplating process

C – Post-treatment processes

These processes will ensure that the surface does not contain any chromium trioxide residue from the electroplating stage.

It is very important to note that the final coated component does not contain any chromium trioxide, so the only potential exposure to chromium trioxide occurs within the company operating the chromium electroplating process – the applicants who have submitted this application for authorisation. So, we are primarily concerned with workplace exposures.

The chromium electroplated components for this specific use require the following performance requirements:

A - corrosion resistance,

B - chemical resistance,

C - wear / abrasion resistance,

D - adhesion,

E – low coefficient of friction,

F – ability to retain oil / grease

g – recyclability.

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

Typical components that require hard chromium plating for this use are:

hydraulic pistons, cylinders and sealing rings, gravure printing components, rotary tooling, shafts and pump rotors, components for the production of textiles and printing, press punches, tooling, dies and moulds. These examples, and many more, with *Technical Performance* as their prime requirement, drive the Market demand and 'failure' of coatings can cause significant supply chain disruption.

3.1.3. Annual volume of the SVHC used

The annual volume of chromium trioxide used in the hard chromium electroplating for this specific use is 16 to 20 tonnes per annum in total.

3.2. Efforts made to identify alternatives

The application for authorisation by the Chromium Trioxide Authorisation Consortium (CTAC) submitted to the European Chemicals Agency (ECHA), stated "as of today, no complete chromium trioxide free process, providing all the required properties to the surfaces of all articles in the scope of this application, is industrially available". This consortium included two of the largest suppliers in Europe of electroplating and surface engineering wet chemistry, clearly confirming the absence of a drop-in replacement for chromium trioxide.

A report by the German Federal Institute for Occupational Safety & Health (BAuA)[4] - Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating states "Using chromium trioxide in functional chrome plating has multiple positive effects based on the characteristics of the coating deposited from chromium trioxide. Key functionalities of coatings, produced by chromium trioxide-based electroplating, especially are good corrosion resistance and excellent wear and abrasion properties combined with hardness, shape retention and very low adhesion. Therefore, functional chrome plating with chromium trioxide has been used for a wide range of applications for more than 50 years. It is very difficult to find a single alternative, neither a substance nor a technology, which replaces the multi-functionality of chromium trioxide generated coatings simultaneously. Until today no one-to-one replacement to chromium trioxide, which meets all the requirements and is economically feasible, has been discovered. In other words: there is no drop-in alternative so far".

Despite this, some the companies that have made this application have made significant efforts to find alternatives. Each of the applicants has provided information on the efforts they have made. Here are a few extracts:

Company 1
We have considered a few alternatives to chrome plating.

Salt bath nitrocarburising can provide the corrosion protection we require but it is not as hard as a chrome plated cylinder. The process also is completed at 580°C which would distort our tubes and require extra machining processes making our product more expensive than the competition.

Blu chrome is another alternative however this process requires a nickel plating process prior to the trivalent chrome process to achieve the corrosion resistance. This estimated cost of this process is 4x that of the current chrome plating. It would also reduce our *capacity by half as we would need to utilise 2 x chrome plating baths to nickel plate. The final hardness of the coating is not as hard as hexavalent chrome plating.*

Company 2

Over the years, we have developed a range of coatings (PharmaCote®) that uses modern physical vapour deposition (PVD) technologies to produce variety of both high and low temp CrN coatings. Our coating range is stated below:

PharmaCote HC (hard chrome)
PharmaCote HC+
PharmaCote EC
PharmaCote EC^{extra}
PharmaCote CT
PharmaCote CTX
PharmaCote CN
PharmaCote CN+
PharmaCote CX
PharmaCote CX+
PharmaCote TN
PharmaCote RS

Through the use of different PVD techniques and temperatures, we have developed a range of coatings which are composed of materials such as Titanium Nitride (TiN), Chromium Aluminium Nitride (CrAlN) and Chromium Nitride (CrN). Along with the coatings, the surfaces of our tooling are engineered to provide a different surface texture in the aid of reducing the surface's co-efficient of friction.

Fundamentally for certain applications and markets there is no alternative replacement for chrome, hence it's continued use in the pharmaceutical industry. We need to be able to use it to compete with global competitors.

Company 3

We explored and invested significantly in trialling an electroless nickel plating with diamond coating. The coating provided corrosion protection and the nickel plate was fairly consistent but the diamond dispersion was not consistent (no guarantee that it would be focused on the blades of the tools which is where the hardness was needed). The wear life was not comparable to the functional chrome plate.

3.2.1. Research and development

The applicants rely on the chemistry suppliers and Universities to conduct research and developments as the costs are prohibitive to small and medium-sized businesses. The sector association, the Surface Engineering Association, keeps abreast of research and development activities on a global scale and has been involved in a number of UK Government and EU funded project to develop alternative coatings. Any information gathered by the SEA will be circulated to the consortium members.

3.2.2. Consultations with customers and suppliers of alternatives

Members of the consortium have been in regular discussions with their customers and the suppliers of surface engineering chemistry and examples of discussions can be seen in section 3.2

3.2.3. Data searches

On behalf of the consortium members, the Surface Engineering Association carries our regular data searches via academic journals and Research Gate. They also maintain regular contact with other key associations around the world such as National Association for Surface Finishing (USA), European Committee for Surface Treatments (CETS), Metal Finishers' Association of India (MFAI).

3.2.4. Identification of alternatives

Following extensive research over a number of years, there are 5 potential alternatives for this use of chromium trioxide for hard chromium electroplating. These 5 alternatives are all "advertised" as suitable alternatives but they are not suitable for this certain, specific application. The 5 potential alternatives are:

A) Using trivalent chromium chemistry
B) Using thermal spraying processes
C) Using electroless nickel
D) Using physical vapour deposition (PVD)
E) Using Nitro-Carburising process

All of these alternatives have been examining by numerous previous applications for authorisation which have been granted a 12-year review period by the European Chemicals Agency / European Commission

Table 1: Shortlisted alternatives.

Number	Alternative name	CAS or EC Number (where applicable)	Description of alternative
1	Trivalent chrome	N/A	Chromium electroplating using a trivalent chromium-based processing solution and subsequent heat-treatment
2	Thermal Spraying	N/A	Thermal spraying to produce a metallic chromium, chromium alloy or other metallic alloy coatings
3	Electroless nickel	N/A	Autocatalytic plating of nickel to produce a nickel phosphorous alloy coating
4	PVD	N/A	Physical vapour deposition of a range of alloy coatings
5	Nitro-Carburising	N/A	Nitro-carburising heat treatment process

3.3 Assessment of shortlisted alternatives

3.3.1 Alternative 1: Trivalent hard chromium electroplating

3.3.1.1 General description of Alternative 1

In this potential alternative process, the chromium trioxide is replaced by a number of other substances to produce a different process technology. Hard chromium electroplating with trivalent chromium chemistry enables the deposition of metallic chromium, with some additional alloying taking place, onto components. The component to be coated is immersed in the trivalent chromium electroplating solution, which contains dissolves trivalent chromium salts, additives such as ammonium salts which act as complexing agents and boric acid which acts as a buffering agent to control the ph of the solution.

The actual composition of the chromium trioxide plating solutions depends on the performance requirement of the coating produced. The most commonly used types of chemistry for this particular type of coating are either sulphate based or chloride based chromium trioxide solutions.

Trivalent chromium electroplating is based on the same principle of electrodeposition as chromium trioxide electroplating but can only be used on simple geometries as the "throwing power" (covering capacity) is currently not sufficient, and could possibly be undertaken using similar plant and equipment as chromium trioxide electroplating. However, there are major differences such as chemical composition of the electroplating solution and its control, the operating parameters and the need for additional ancillary equipment such as ion exchangers, extra process steps to passivate the surface and specialised wastewater treatment processes. This will involve significant capital investment for SMEs.

3.3.1.2 Availability of Alternative 1

For functional chromium electroplating, considerable research has been carried out and has developed laboratory and pilot plant scale. The main chemical suppliers have development projects looking into the adaptations required to the trivalent chromium process in order to try and meet the specific requirements for functional chrome plating. In 2017, Atotech launched what they claimed to be the first trivalent chard chromium plating process but there are very few plating lines in operation using this method due to its failure to meet the specific performance requirements.

3.3.1.3 Safety considerations related to using Alternative 1

The following is an extract from the application for authorisation submitted by the chromium trioxide authorisation consortium, including 2 of the main suppliers of process chemistry in the UK.

As the alternative is not technically feasible, only classification and labelling information of substances and products reported during the consultation were reviewed for comparison of the hazard profile. Based on the available information on the substances used within this alternative, chromium (III) chloride would be the worst case with a classification as Skin Irrit. 2, Eye Irrit. 2, Acute Tox.

In general, the trivalent electroplating processes are less toxic than chromium trioxide plating due to the oxidation state of the chromium. Cr(III) solutions do not pose serious *air emission issues, but still pose the problems of disposal of stripping solutions (depending on the type of stripping solution) and exposure of staff to chrome dust during grinding. In addition, there is a certain risk of Cr(VI) being generated during the plating process (anodic oxidation of Cr(III) ions). This is why appropriate security precaution and process management has to be adopted to prevent the formation of Cr(VI).*

The Cr(III) bath electrolyte solution typically also contains a high concentration of boric acid, which is an SVHC (Repr. 2; H361) included on the candidate list and currently on the 6th recommendation for inclusion in Annex XIV. Overall, the transition from Cr(VI) to Cr(III) technology constitutes a shift to less hazardous substances, despite one of the used alternative substances is itself classified for mutagenicity and carcinogenicity. Hence, any replacements will need to be carefully evaluated on a case by case basis.

It should be understood that replacing chromium trioxide involves the use of many more substances rather than just one substance. The following are typically required in trivalent chromium electroplating solutions:

Chromium Sulphate EC: 233-253-2 CAS: 10101-53-8
Chromium Chloride EC: 233-038-3 CAS: 10025-73-7
Chromium Trichloride Hexahydrate EC: 629-714-6 CAS: 10060-12-5
Boric Acid EC: 233-139-2 CAS: 10043-35-3
Ammonium Chloride EC: 235-186-4 CAS:1215-02-9

According to the ECHA chemicals database, Chromium Trichloride Hexahydrate is classified as toxic to aquatic life with long lasting effects, causes serious eye irritation, is harmful if swallowed, may cause respiratory irritation, causes skin irritation, may be corrosive to metals and may cause an allergic skin reaction. So, any potential alternative needs to be fully evaluated and assessed before use.

On a positive note, using trivalent hard chromium electroplating would remove the use of chromium trioxide from the workplace. However, it has been clearly demonstrated that by working in accordance with best practice, chromium trioxide can be used with potential exposures similar to background levels.

3.3.1.4. Technical feasibility of Alternative 1

Process Control

The composition of trivalent chromium electrolytes is far more complex and considerably more sensitive to contaminants than electrolytes based on chromium trioxide. The concentrations of contaminants need to be regularly monitored and selective ion exchangers are required to remove metallic contaminants that would otherwise impact on the process. The other additional process substances (such as wetting and buffering agents) need to be frequently monitored to ensure that the process remains in control.

Anodes

Trivalent chromium processes use platinum-coated, titanium anodes which are considerably more expensive than the traditional lead anodes and regularly have to have their effectiveness tested. There are no established findings about their life expectancy yet, so as there are long delivery times of eight to ten weeks, a spare set always has to be kept on hand. It is currently only possible to carry out checks on the effectiveness of these special anodes by external testing companies due to the nature of the tests involved such as XRF analysis and arc atomic emission spectroscopy.

Rinsing technology

The requirements with regard to rinsing technology and waste-water treatment are also clearly higher than for traditional chrome plating due to the high concentrations of boric acid used as a buffer substance as well as the complexing agents present in the trivalent chromium electrolytes.

Passivation

Passivation must be carried out just after the chromium electroplating phase. This can be done chemically or electrochemically. There are different types of passivation systems for this, but at present, they all contain chromium trioxide or other substances containing the hexavalent form of chromium. The passivation stage is necessary to provide the coating with similar performance characteristics.

Internal coating

Currently available trivalent hard chromium plating solutions are not suitable for coating complex geometric shapes due to the slow reaction kinetics. This results in the insufficient availability of trivalent chromium ions and an enrichment of impurities, such as iron ions, that disrupt the coatings process.

Examining some the specific technical requirements of the chromium electroplated coating for this particular use we see:

Corrosion resistance – Extensive studies have been undertaken and referenced in other applications for authorisation for the continued use of chromium trioxide. To summarise, the corrosion resistance of electroplated chromium using trivalent chromium chemistry is dependent on many differing parameters. These include the type of process chemistry being used, the electroplated under-layers and any potential post-treatments used to enhance the corrosion resistance. Based on the information supplied by the members of the consortium, the corrosion resistance of chromium electroplating using trivalent chromium process chemistry does not currently meet the performance requirements for this particular use.

Chemical resistance – information provided by the members of the consortium and given in previous applications for authorisation show that the chemical resistance of electroplated chromium from trivalent chromium chemistry is lower than when using chromium trioxide. Based on the information supplied by the members of the consortium, the chemical resistance of chromium electroplating using trivalent chromium process chemistry does not currently meet the required performance.

Wear / abrasion resistance – Although these two terms are often seen as interchangeable, wear is the loss of material from the surface of a material and abrasion is one of the actions which can cause wear. The chromium plating produced from trivalent chemistry tends to have a lower hardness and therefore lower wear resistance, although improvements are continued to be made by modifying process parameters. Based on the information supplied by the members of the consortium, the wear /

abrasion resistance of chromium electroplating using trivalent chromium process chemistry does not currently meet the required performance characteristics. This is due to the trivalent chromium deposit having an amorphous microstructure compared to the fine-grained polycrystalline microstructure of hard chromium electroplating produced by using chromium trioxide.

Adhesion – the adhesion performance of the chromium electroplating from trivalent chromium chemistry does not currently meet the required performance characteristics.

3.3.1.5 Economic feasibility of Alternative 1

Chromium electroplating from trivalent chromium solutions tend to be more expensive but recent advances have led to this gap closing when all factors, apart from the capital investment required, are taken into consideration:-

Initial solution make-up – this is an initial one-off cost to make-up the trivalent chromium process. Account also has to be taken of the potential disposal costs of the chromium trioxide containing process solution, if this potential alternative were to be adopted.

Regular solution maintenance – as the trivalent chromium process chemistry requires more substances and additives, costs are higher.

Ion exchange – ion exchange units will have to be purchased (capital investment & increased energy consumption) to ensure that any impurities in the trivalent chromium process are removed. This removal is a continuous process.

Wastewater treatment - The cost of wastewater treatment is significantly higher than when using chromium trioxide. The main reason for this is the complexing agents present in trivalent electrolytes, that hamper the hydroxide precipitation not only of trivalent chromium, but also of other metals in the wastewater such as nickel.

Process Analysis – a typical chromium trioxide plating solution will require no more than 2 hours of analysis time each week. A typical trivalent chromium plating solution will require around 2 hours of analysis each day.

Re-Engineering – the process line will have to be re-engineered to account for the extra ion exchange processes and the extra rinsing requirements to avoid impurities and to allow for the passivation stage. There is often simply no extra space to re-engineer process lines and certainly not to run both systems in tandem during trial periods.

Anode Materials – the trivalent chromium process uses platinised titanium anodes rather than lead.

Energy Consumption – as the trivalent chromium process uses a lower current density, less energy is consumed. However, it is often found that the solution has to be cooled during operation, so this will lead to an increase in energy.

3.3.1.6 Suitability of Alternative 1 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of trivalent chromium process solutions is not considered as a suitable alternative for this particular use.

3.3.2 Alternative 2 – Thermal spraying processes

3.3.2.1 General Description of Alternative 2

Thermal spraying alternatives have been extensively researched by many sectors, including commercial and military aircraft sectors. Thermal spraying includes several technologies. Materials suggested for the thermal spray technologies include WC-Co, WC-CoCr, Cr3C2-NiCr, Ni5Al and TiN. Thermal spray technologies require extensive training and expertise to master. If done well, a higher quality coating with long service life will be achieved. Thermal spraying is currently applied mainly on rotating cylinder surfaces or coatings of small parts of an object. One of the more used spray-technologies is the High Velocity Oxy-Fuel (HVOF) spray coating. The principle of the HVOF coating technology is to use a supersonic flame, which accelerates particles of the coating material to high velocity. When the coating material hits the substrate, these high-velocity particles form a very coherent, low porosity coating. Hardness of the coating is in the range of 1100-1400 HV. Its wear resistance and corrosion protection properties can be better than chromium trioxide based hard chromium electroplated coatings. The coating process usually results in rough surfaces, which is why the coating usually requires some post-deposition machining. A major disadvantage of all thermal spraying processes is that they are a line-of-sight application. Therefore, coating of inner surfaces and complex geometries is very difficult, if not impossible. In addition, temperature of the coated surface will increase to the range of 150-400°C during the coating process, which can distort and damage the substrate material being coated. Therefore, the technology is only applicable on substrate material that can withstand the high process temperatures.

3.3.2.2 Availability of Alternative 2

Thermal spraying coatings are widely available and are used extensively in the semiconductor, microelectronics and cutting tool industries. The biggest drawback is the cost of the capital investment required to purchase the thermal spraying machinery and the subsequent re-training of employees.

3.3.2.3 Safety considerations related to using Alternative 2

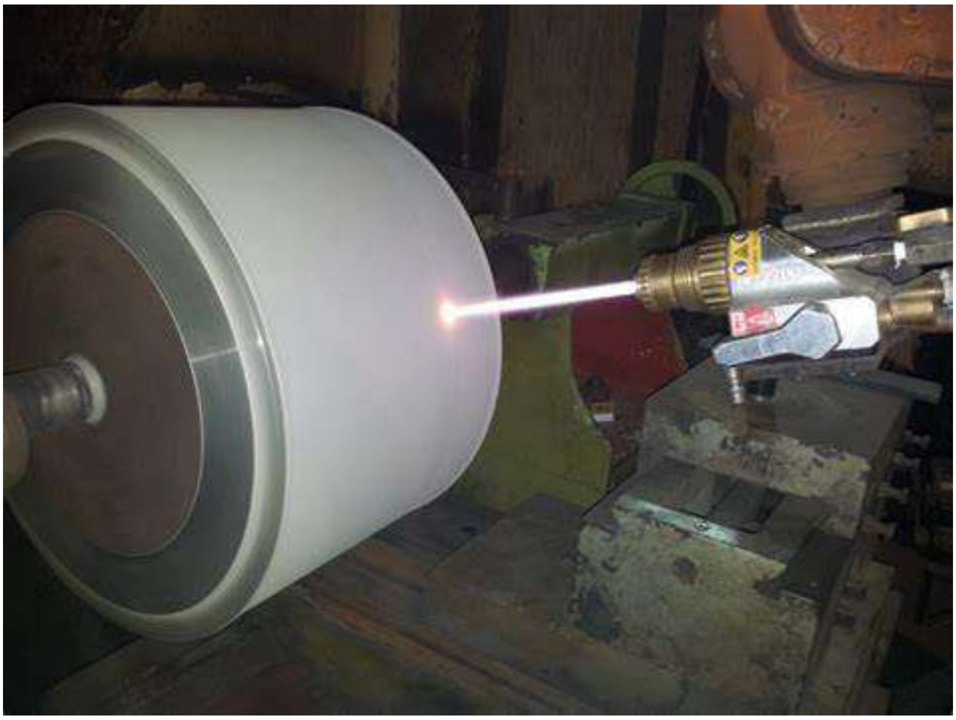
In terms of substance / chemical use, thermal spraying type coatings show a reduction in risk as it is possible that they do not use any substances that are classified as SVHC – substances of very high concern.

However, a significant re-training programme would be required in order for the current employees to firstly understand the thermal spraying process, know how to use it safely and how to maintain it in a safe working manner. The current electroplating process does not use any thermal spraying technologies.

3.3.2.4 Technical feasibility of Alternative 2

Thermal spraying coatings have the following technical limitations when being considered for this particular use:

Geometry: Thermal spraying processes are line-of-sight processes – the coating is applied in a straight line:



It can clearly be seen that this process is not suitable for complex geometries and internal surfaces.

Pre-treatment: The surface must be roughened (shot blast) before thermal spraying to ensure satisfactory adhesion as the deposition method is primarily mechanical.

Surface roughness: The finished surface will normally require further processing such as surface grinding to achieve a suitable level of surface roughness.

When considering the technical feasibility of alternative 2, it is not considered to meet the technical requirements for this use.

3.3.2.5 Economic feasibility of Alternative 2

If a change from electroplated chromium using chromium trioxide to a thermal spraying coating was envisaged, the installation of a completely new production line would be required as thermal spraying coatings cannot be produced on existing electroplating lines – it is a complete change of technology.

Feedback showed that the typical operating costs were often 30-40% higher and new, technical knowledge will be required. Typical members of this consortium have built up many years of technical knowledge and skills, and it would take them many years to fully understand this new type of process.

When considering the economic feasibility of alternative 2, it is not considered to be a valid alternative at present.

3.3.2.6 Suitability of Alternative 2 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of thermal spraying processes are not considered as suitable alternatives for this particular use.

3.3.3 Alternative 3 – Electroless Nickel Plating

3.3.3.1 General Description of Alternative 3

Electroless nickel is a hard, silver coloured coating comprised of nickel alloyed with between 4 and 14% phosphorus. It can also be alloyed with boron, but the phosphorus alloy is the most common. It is deposited by immersion of parts in a solution of nickel salts and reducing agents at a temperature of 90°C. Although it has the appearance of an electroplated coating, the process is purely chemical, so that deposition is evenly distributed over the part, including internal and external corners.

Electroless nickel is particularly applicable for plating inside holes with small internal diameters and complex parts. The hardness of deposited electroless nickel-phosphorous plating is in the range of 500-700 HV, which can be increased up to 1100 HV with subsequent heat treatment. The temperature required for the heat treatment is usually around 300-400°C, so this limits the substrate materials that can be used. The corrosion resistance properties of electroless Ni plating are good, but the heat treatment needed for higher hardness will reduce the corrosion resistance performance.

Maintaining the correct bath chemistry is complex and frequent bath disposal as toxic waste is required, unless expensive auto-regeneration technology is used.

3.3.3.2 Availability of Alternative 3

Electroless nickel plating has been available since the 1960s and through continual research and development, it has become a widely used process for specific products, environments and industry sectors.

3.3.3.3 Safety considerations related to using Alternative 3

A major disadvantage of electroless Ni plating is that nickel is already placed on the US Environmental Protection Agency’s 17 targeted substances list, the US Agency for Toxic Substances and Disease Registry Substance Priority List and according to the classification provided by companies to ECHA in REACH registrations, nickel causes damage to organs through prolonged or repeated exposure, may cause cancer by inhalation, is toxic to aquatic life with long lasting effects, may damage fertility, is suspected of causing genetic defects, is suspected of causing cancer, may cause an allergic skin reaction and may cause allergy or asthma symptoms or breathing difficulties if inhaled. In addition, nickel ions that can be released from the coating are known to cause dermatitis (nickel allergy). Therefore, electroless nickel cannot be considered as a suitable alternative.

3.3.3.4 Technical feasibility of Alternative 3

The main technical reason why electroless nickel plating is not considered suitable is the need for a subsequent heat treatment process to achieve the required coating hardness but this then changes the micro-structure of the coating and reduces its corrosion resistance.

3.3.3.5 Economic feasibility of Alternative 3

Electroless plating can be considered as a potential drop-in alternative, as the same pre-treatment tanks could be utilised, but new process tanks (where plating occurs) have to be purchased. This would involve significant capital investment and for large components, could easily cost £100,000. The production costs are at least 2-3 times higher than the chromium trioxide based functional plating, because the plating time is long and more energy is required to maintain the bath at the operating temperature. For making thicker deposits, products need to stay in the plating bath several hours longer than with chromium plating. This means that the productivity of the applicants will drop significantly, making the business unprofitable and therefore unsustainable. For these reasons electroless Ni plating is considered to be expensive technology and economically unfeasible.

3.3.3.6 Suitability of Alternative 3 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of electroless nickel plating is not considered as a suitable alternative for this particular use specifically because of the health issues surrounding nickel.

3.3.4 Alternative 4 – PVD Processes

3.3.4.1 General Description of Alternative 4

PVD – Physical Vapour Deposition, refers to a vacuum coating process in which a film of coating material is deposited atom by atom on the substrate material by the process of condensation from the vapour phase to the solid phase. The two most common PVD Coating processes are Sputtering and Thermal Evaporation. Sputtering involves the bombardment of the coating material known as the target with a high energy electrical charge causing it to "sputter" off atoms or molecules that are deposited on a substrate. Thermal Evaporation involves elevating a coating material to the boiling point in a high vacuum environment causing a vapor stream to rise in the vacuum chamber and then condense on the substrate.

The first patent for a PVD type coating was filed by Edison in 1884 and issued in 1894 and mentioned electro vacuous deposition. Since then, many technological advances have been made with the process and process equipment.

Titanium Nitride (TiN), Chromium Nitride (CrN), Titanium Aluminium Nitride (TiAlN), Titanium Boron Nitride (TiBN) are some examples of PVD coatings.

3.3.4.2 Availability of Alternative 4

PVD coatings are widely available and are used extensively in the semiconductor, microelectronics and cutting tool industries. The biggest drawback is the cost of the capital investment required to purchase the coating machinery in order to produce and maintain the vacuum and vaporisation of the coating material.

3.3.4.3 Safety considerations related to using Alternative 4

In terms of substance / chemical use, PVD type coatings show a reduction in risk as they currently do not use any substances that are classified as SVHC – substances of very high concern.

However, a significant re-training programme would be required in order for the current employees to firstly understand the PVD process, know how to use it safely and how to maintain it in a safe working manner. The current electroplating process does not use any vacuum or vaporising technologies.

3.3.4.4 Technical feasibility of Alternative 4

PVD coatings have the following technical limitations when being considered for this particular use:

Corrosion Resistance: PVD coatings can suffer from pinholes, which then leads to pitting in typical use. Research is still ongoing and combination PVD coatings are now offering enhanced corrosion resistance. Currently the PVD coatings do not meet the corrosion resistance requirements for this use.

Vacuum/Geometry: The requirement of a vacuum chamber limits the size and the type of parts that can be coated. It should also be remembered that PVD coatings are line of sight processes and are not suitable for complex geometries and large parts, such as car bumpers.

Operating parameters: The process conditions for PVD require sub-atmospheric pressures and temperatures between 150 and 600°C. Process temperature, especially towards the upper limit can restrict the substrate materials that can be coated.

Cleanliness: PVD coatings require an atomically clean surface because they are highly sensitive to contaminants (e.g. water, oils and paints) on the surface to be coated. In fact, inadequate or non- uniform ion bombardment leads to weak and porous coatings and is the most common cause of failure in PVD coating. Therefore, an extremely efficient cleaning and drying method is required for this process.

Hardness: PVD Coatings can produce very high hardness coatings, but this can lead to internal stresses being developed during processing.

Wear Resistance: wear resistance is comparable if not superior to electroplated chromium but because the coating is extremely thin (hence the name thin film deposition), the long-term wear can be limited.

When considering the technical feasibility of alternative 4, it is not considered to meet the technical requirements for this use.

3.3.4.5 Economic feasibility of Alternative 4

Due to the technical shortcomings of the PVD coating processes, the following overview has been obtained through industry contacts and members of the consortium:

If a change from electroplated chromium using chromium trioxide to a PVD Coating was envisaged, the installation of a completely new production line would be required as PVD coatings cannot be produced on existing electroplating lines – it is a complete change of technology.

The throughput of a typical PVD coating process (including cleaning & loading) would be considerably lower than that for electroplating by a factor of almost 50%. The initial start-up costs for a PVD coating process would be prohibitive for all members of this consortium. A new PVD Process line capable of processing the typical components for this use would cost more than the total annual sales value of the companies applying for authorisation for this use.

Feedback showed that the typical operating costs were often 30-40% higher and new, technical knowledge will be required. Typical members of this consortium have built up many years of technical knowledge and heritage skills, and it would take them many years to fully understand this new type of process.

When considering the economic feasibility of alternative 4, it is not considered to be a valid alternative at present.

3.3.4.6 Suitability of Alternative 4 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of PVD processes is not considered as a suitable alternative for this particular use.

3.3.5 Alternative 5 – Nitro-Carburising Process

3.3.5.1 General Description of Alternative 5

Nitrocarburising is a low-temperature low-distortion "thermochemical" heat treatment carried out to enhance the surface properties of finished or near-finished ferrous components. Nitrocarburising, with processing times of 30 minutes - 5 hours, involves enrichment of the surface with both nitrogen and carbon to impart a thin iron-carbonitride "compound layer" supported by a nitrogen-bearing "diffusion zone". Conducted at temperatures of 560-580°C ("ferritic nitrocarburising") or 590- 720°C ("austenitic nitrocarburising"), the process may be completed by quenching and can involve additional steps to promote certain properties. Nitrocarburising is a generic term covering salt-bath treatments, such as Tufftride, and the equivalent processes conducted in gaseous atmospheres and known by a host of trade names.

3.3.5.2 Availability of Alternative 5

Nitrocarburising is widely available.

3.3.5.3 Safety considerations related to using Alternative 5

There are two main types of processing – molten salt bath or in a gaseous environment within a heat treatment furnace.

In the molten salt bath process, caustic cyanide solutions put operators at risk of serious injury if molten salt contacts their skin. Parts with unsealed seams or complex geometries can trap the salt solution even after rigorous rinsing. That puts workers at risk for additional caustic exposure if the salt shakes loose later and can increase the risk of corrosion damage to parts. Molten salt baths cannot be turned off. The salt must remain molten, so baths must stay heated even when they're not in use.

When using furnaces and a gaseous environment, great care needs to be taken to ensure that employees are not exposed to risk from gas leakages and heat injuries.

3.3.5.4 Technical feasibility of Alternative 5

In ferritic nitrocarburising, the resultant compound layer, with good lubricant-retention characteristics, is responsible for the major benefit of high resistance to wear, scuffing, galling and seizure. The diffusion zone contributes improved fatigue resistance if components are quenched after nitrocarburising. An increase in corrosion resistance can be improved upon further by post-oxidation treatment which imparts an aesthetically-pleasing black finish; additional polishing and oxidation steps can yield a surface finish rivalling hard chrome plating, in terms of high corrosion resistance combined with low coefficient of friction. However, all of these processes are not commonly found alongside hard chromium plating, so there would be a considerable amount of training involved to upskill the existing workforce.

3.3.5.5 Economic feasibility of Alternative 5

The nitro-carburised coating cannot be machined as this will destroy the coating and the properties that it has imparted. To process large components will require a large furnace / salt bath and this will entail significant levels of capital investment, in the region of £80,000. This alternative cannot be considered as a suitable alternative.

3.3.5.6 Suitability of Alternative 5 for the applicant and in general

Whilst considerable research and development has been completed and is still on-going, the use of the Nitro-Carburising process is not considered as a suitable alternative for this particular use.

3.4 Conclusion on shortlisted alternatives

Whilst all the five potential alternative coatings can, and have, replaced chromium trioxide in hard chromium plating for specific products with specific technical and performance requirements, none of them are currently considered to be viable alternatives providing the complete technical and performance characteristics for this particular use.

4 SOCIO-ECONOMIC ANALYSIS

4.1 - Continued use scenario

4.1.1 Summary of substitution activities

The applicant and several other members of this group of users, have researched the potential alternatives to chromium trioxide and have received sample components from suppliers of the potential alternative process equipment or material.

On assessment, none of the alternatives satisfy all the performance and aesthetic criteria required by the end users of the articles being coated. The most important performance criteria being corrosion resistance, wear resistance, hardness and chemical resistance with no alternative able to satisfy these criteria.

4.1.2 Conclusion on suitability of available alternatives in general

As a result of the unacceptability of alternatives, to the end users, the conclusion is that the applicants have no available or potential alternative processes likely to be introduced for the foreseeable future.

Therefore, it is not possible to produce a substitution plan.

4.1.3 R&D plan

The group members are either SMEs, as defined in the EU recommendation 2003/361, and as such do not have access to funds to enable individual R&D activity into surface treatment processes which are not core activities and, in most cases, do not have the floorspace or manpower to accommodate the necessary process facilities.

The applicants must, therefore, rely on R&D carried out by the major process chemistry suppliers and Universities as the costs are prohibitive to micro, small and medium-sized businesses. The sector association, the Surface Engineering Association, keeps abreast of research and development activities on a global scale and has been involved in a number of UK Government and EU funded projects to develop alternative coatings. Any information gathered by the SEA will be circulated to the consortium members.

4.2 Risks associated with continued use

Given that all of the results from the Workers biological monitoring reports are within (or below) the range expected for the unexposed population i.e., <10µmol/mol creatinine and that there are no discharges of chromium trioxide to the environment, there is no excess lifetime risk to individuals (worker or general population) or to the environment. However, as chromium trioxide is classified as a non-threshold carcinogen and using the dose response relationship for exposure to chromium trioxide developed by the Risk Assessment Committee of the European Chemicals Agency, there is an excess lung cancer risk of 2×10^{-3} by considering the worst-case scenario.

The worst-case assessment of worker health risks within this socio-economic analysis utilises the results of a study endorsed by ECHA identifying the reference dose response relationship for carcinogenicity of hexavalent chromium. These results are acknowledged to be the preferred approach of the RAC and SEAC and therefore have been used as a methodology for the calculation of work cancer risks in this socio-economic analysis.

The following steps are therefore necessary to complete the health impact assessment:

1 – Assessment of worker exposure (actual measurements)

2 – Estimation of additional cancer deaths relative to the baseline lifetime risk

3 – Estimation of additional non-fatal cancer based on survival rate statistics

4 – Monetary valuation of fatal and non-fatal cancer risks

Following the worst-case approach, the combined worker exposure values from the corresponding chemical safety report, section 10, are used to make the assessment of health impacts. Following the ECHA methodology where the applicant only provides data for

the exposure to the inhalable particulate fraction, it will be assumed that all particles were in the respirable size range and only lung cancer need be considered.

For the lung cancer calculation, excess lifetime risk (ELR) is defined as the additional risk of dying from cancer due to exposure of toxic substances incurred over the lifetime of an individual. From the ECHA RAC the unit of occupational excess lifetime mortality risk is 4 X 10^{-3} per μg Cr(VI)/m^3

Table 2: Excess lung cancer mortality risk to workers covered by this application

A	Inhalation exposure weighted average $\mu g/m^3$	18.8
B	Excess risk unit coefficient	4×10^{-3} per $\mu g/m^3$
C	Excess risk for 40 years (A x B)	75.2×10^{-3}
D	Excess risk per year (C/40)	1.88×10^{-3}
E	Number of workers exposed	39
F	Total annual excess risk (number of cases)	0.07332

The individual development of cancer may be fatal or non-fatal whereas the dose response function considers only fatal cancer. It therefore follows that the excess risk of cancer is higher than the excess risk of fatal cancer.

According to Cancer Research UK the following table can be developed:

Table 3: Age-standardised, five-year survival rates for lung cancer in the UK, 2013-2017

Relative cumulative survival	Non-fatal/ fatal ratio
16.2	0.193

This means that for every fatal case of lung cancer, there is an additional 0.193 non-fatal cases in the UK. This equates to 0.0003 non-fatal cancer cases associated with this application.

Table 4: Values for fatal and non-fatal cancer taken from ECHA Guidance using December 2003 exchange rate of €1.42 / £1

	2003	GDP factor	2020
Value of statistical life	£740,845	133.95	£992,362
Value of statistical life (sensitivity)	£1,590,141		£2,129,994
Value of cancer morbidity	£370,423		£496,181
Value of cancer morbidity (sensitivity)	£795,070		£1,064,997
Value of cancer fatality	£1,111,268		£1,488,543
Value of cancer fatality (sensitivity)	£2,385,211		£3,194,990

The GDP factor is the change in UK GDP between 2003 and 2020 as per the UK Office for National Statistics and allows for inflationary impacts to be included in the assessment.

Table 5: Estimated monetary value of annual risk of lung cancer from chromium trioxide exposure for this application.

	All sites combined
Fatal cancer risk per year	0.07332
Annual cost of fatal cancer risk	
Per case £1,488,543	£109,139.97
Sensitivity £3,194,990	£234256.67
Non-fatal proportion	0.193
Non-fatal cancer risk per year	0.0183
Annual cost of non-fatal cancer risk	
Per case £496,181	£9,080.11
Sensitivity £1,064,997	£19,489.46
Total annual cost of cancer	£118,220.08
Sensitivity	£253,746.13

These figures used the same methodology of those submitted by Grohe AG who were granted a 12-year review period for their authorisation.

Given that the results show no increased risk over that of the General Population and that emissions to atmosphere are very low and likely to be atmospherically reduced to chromium trioxide, the implications of a non-use scenario will only affect the applicants and their customers.

Similarly, the continued-use scenario does not give rise to any additional economic burden toward health or environment.

4.3 Non-use scenario

If authorisation is refused, there would be an immediate closure of the chromium plating facility and the applicants will be unable to continue trading as a result. This because the chromium plating is an integral part of the product manufacturing process and, without it, the final product is unusable due to premature failure rates or unacceptable hygiene function. This will place the workers at immediate risk of unemployment and the applicants with significant costs associated with chemical disposals, redundancy, asset disposal and premises sale.

4.3.1 Summary of the consequences of non-use

In the non-use scenario, the applicants will cease trading and customers will resort to purchasing the same products and coatings (chromium trioxide plating) from overseas i.e., outside of The UK and The EU resulting in increasing the UK's trade deficit without removing the substance from Global use.

Larger customers with a regular requirement for the process may also take the decision to re-locate to the geographical supply base i.e., Off-shoring.

The job losses would total 685 from the applicants with an added risk within their customers employee base of 367,750 staff.

The short-term effect to the economy would be the loss of approximately £75.77M GDP (per annum) and the contribution to UK Treasury from taxes, etc.

In the medium-term, should customers decide to relocate, the loss to UK GDP would be significant but incalculable, as these are predominantly Global businesses with some manufacturing presence in The UK (based on "top 5" turnover).

The economic effect on the suppliers, of chromium trioxide, to the applicants cannot be quantified in this report.

The Group members in this consortium able to research, and/or trial, potential alternatives have submitted samples and consulted with their customers.

The customer responses to these are (ref. Section 3.2):

"extra machining processes making our product more expensive than the competition"

and

"another alternative however... process requires nickel plating prior to the trivalent chrome to achieve the corrosion resistance. ...estimated cost is 4x that of the current chrome plating... reduce our capacity by half....final hardness ….. not as hard as hexavalent chrome"

"certain applications and markets...no alternative for chrome, hence continued use in pharmaceutical industry. We need to be able to use it to compete with global competitors."

"invested significantly in electroless nickel plating with diamond coating.... wear life not comparable to chrome plate."

4.3.2 Identification of plausible non-use scenarios

Non-use Scenario 1

Shut down of chrome plating process, resulting in company closure.

Sections 3.3.1.4, 3.3.2.4 and 3.3.3.4 detail the technical performance of each of the potential alternatives and, while some of the requirements are met, there are none that meet the 'basic' criteria of visual appearance (colour) and wear resistance.

These are critical requirements for this market sector hence, section 3.4 concludes that "none of them are currently considered to be viable alternatives for this particular use."

The customer "demand" is for technical performance.

As there is no alternative process, the existing chromium trioxide facilities will close, and staff will be redundant.

The company must dispose of all materials, using specialist contractors to handle the hazardous waste thereby, incurring unrecoverable costs. The process facility is then dismantled and disposed to waste/scrap recovery incurring further specialist contractor cost because of the contaminated equipment.

Removal and clean-up costs reduce company balance sheet value affecting the ability to pay both statutory and commercial creditors and, possibly, staff redundancy payments.

Any Service Level Agreements (SLA) that cannot be satisfied will be subject to contingent cost claims from the customers so reducing the value of the remaining income from invoices issued prior to closure.

Non-use Scenario 2

Change to worse performing alternative.

Section 3.3.1 details the trivalent chrome process, its operation, and its technical characteristics.

Trivalent chrome processes are unstable and energy intensive. Using this process incurs additional analytic and control staff, consumes additional energy, and fails to provide the technical performance to the product.

These result in increased payroll cost, increased energy cost and re-processing cost (if possible). Disposal of existing chromium trioxide is done by specialist contractors. Installation of additional equipment relative to trivalent chrome processing is done – involving closure of the production facility and addition of bunding area, tanks, controls, services, and utilities.

Loss of business due to stoppage of process will occur in the **short-term**.

On restart, the final product fails performance standards or fails prematurely in service resulting in customer rejects and rework cost and/or scrappage of components – incurring replacement cost.

Medium-term, loss of business due to quality and throughput failures. Reduction in staffing levels due to loss of business.

Customers source products with technically acceptable coating (chromium trioxide) from available sources (overseas).

Long-term, cost burden and inability to supply consistent product that performs technically result in loss of customers and significant reputational damage.

Customers source "original" finish (chromium trioxide) from available sources (overseas).

This results in closure of uneconomic process following financial losses due to failures in quality and delivery.

Staff are redundant when process stops.

Disposal and removal cost incurred. Business closes.

4.3.3 Conclusion on the most likely non-use scenario

NuS 2 is very unlikely to occur as the applicants do not have the financial capacity, floorspace or number of staff required to install a process which is known to be unacceptable.

The most likely NuS is scenario 1 i.e., Off-shoring of process and closure of applicants' business.

Immediate effect on local economy with added potential of larger customers re-locating to supply base geographic area and affecting UK GDP.

This market sector is very demanding and are concentrated on achieving a long-lasting, technically acceptable product. This fact alone, determines that the customer will demand the chromium trioxide process and this will incur transport costs and delays resulting from extended supply routes – these additional costs and delays will result in significantly inflated costs.

Sourcing this process overseas will have a negative impact environmentally resulting from the emissions from transport and will "export" the chromium trioxide work to less well-regulated areas.

4.4 Societal costs associated with non-use

In the continued use scenario, it is expected that there will be some additional costs associated with testing, reporting and control systems resulting from conditions applied to the authorisation approval. Although this will be contingent cost to the applicants it is very likely to be passed through the supply chain in the form of price increases therefore would not be additional cost to the applicants.

In the Business as Usual (BaU) case there would be no effect on the economics of the process or product. Employment would continue at the current levels and contributions to the local economy and national GDP would be stable.

As there are no increased health effects to either the workers or the general population, there would be no economic effect to the health or social services.

In the medium to longer term, it is expected that business levels will increase. This will result in additional turnover and employment in the supply chain thereby increasing the economic contribution of the sector.

As the share of the customers sales value resulting from chromium plated parts cannot be quantified, the combined turnover value of the applicants (£75.77M) is used as the contribution to GDP value.

Thereby: **£75.77M GDP value.**

In the non-use scenario the sales value (£75.77M GDP) would be lost because of closure of the applicant businesses. Any export value (not quantified) would be lost and the remainder of the estimated £75.77M GDP value would be replaced by import cost.

This would effectively more than double the effect to the UK trade balance as there would be transportation and additional inventory costs to be factored into the cost of supply.

As this is a demand driven product, it is not possible to quantify the financial impact on the customer supply chain.

In this case the cost calculations take account of the unemployment costs associated with the closure of the applicants' businesses. Because of the numerous companies involved and the wide age demographic that is likely, it is assumed the average age of the workers to be 40 i.e. 20 years old = newly skilled, 60(+) years old highly skilled therefore assume the mid-value as the average for the purpose of this assessment.

It is assumed that all those workers made redundant as a result of the non-use scenario and closure of the applicants businesses would experience a period of temporary unemployment. This assumption is based on the understanding that the workers are generally highly skilled and therefore likely to regain employment within a relatively short period.

Using a conservative approach, the estimated unemployment periods and resultant costs will be calculated using data published by the Office for National Statistics (ONS) 14 June 2022. These data show a 'total' unemployment rate of 3.9% but, a rate of 27.4% for those aged 16-64.

The 'total' figure is used so that there is no bias to the resultant costs even though workers in this industry are predominantly male. Further, it is assumed that re-employment within the first year will be within 3 months and that the rate of re-employment is constant year-on-year and that re-employment is achieved at the mid-point of the second and subsequent years i.e. 6 months unemployed in that year.

It can be seen from table 6 that it is expected that all workers will be re-employed by 4 years after redundancy.

Table 6: Annual unemployed by year following closure

Average salary cost = £31772 (ref. ONS April 2021)

Permanent Workers		Social cost (£77/week – 2022)	Lost Earnings (net avg salary)
685	2023	£1,249,318	£8,664,102
188	2024	£342,313	£3,456,300
51	2025	£93,794	£947,026
14	2026	£25,700	£259,485
4	2027	£7,042	£71,099
1	2028	£1,929	£19,481
TOTALS		**£1,720,096**	**£13,417,494**

In all cases, conservative estimations and assumptions have been used to ensure that the socio-economic impacts of the non-use scenario have not been overestimated. Further, there are likely to be a number of additional negative effects which have not been quantified or monetised due to a lack of suitable data and/or information. These include temporary reductions in output and employment in the applicants' supply chains and in the local economies surrounding the affected manufacturing sites.

4.4.1 Economic impacts on applicants

In the non-use scenario, the applicants' businesses will close resulting in total loss of profit but will remove cost of manufacturing i.e., raw material, utilities, payroll, etc.

However, there will be costs incurred because of redundancy payments (unquantifiable. Values subject to workers age, service, etc.), disposal of residual stock and process chemicals (unquantifiable. Subject to analysis and volumes).

Also, disposal of fixed assets (process equipment, etc.) is likely to be for 'scrap' value only as there will be no market in the UK for this equipment. Financial value of this scrap will result in a reduction of balance sheet values for fixed assets.

Once chemical disposal, clean-up and asset disposal are complete, the property (buildings & land) can be sold. Current industrial property values are relatively high (2022) but, in this scenario, there will be numerous properties available which may serve to depress the market value.

Again, for the purposes of this assessment, the costs are assumed to equal the reduction in manufacturing cost, the balance sheet value and potential return on asset sale.

As the applicant will need to finance the disposals and clean-up costs, the probability is that they will enter Administration or Liquidation putting the immediate burden of redundancy cost on to the Public Purse.

4.4.2 Economic impacts on the supply chain

In the non-use scenario there will be an immediate effect on the customer base in that the only option will be to purchase the same goods and services from outside the UK/EU.

This will increase lead-time, costs, and reduced service levels.

Cost increases will be passed on to their customers who will already be suffering delayed supply and possibly result in cancellation of supply contracts and, what are currently exports of goods and services will probably be lost to the overseas suppliers who will deal directly with the export customers.

4.4.3 Economic impacts on competitors

While there is some use of alternative processes within the UK these have been dismissed by this market sector as being unacceptable.

This means there would be no economic advantage achieved by any UK based competitor who are using an alternative. The entire value of the customer base will be lost to foreign suppliers.

4.4.4 Wider socio-economic impacts

In addition to the socio-economic impacts described in the previous sections, the non-use scenarios might be associated with wider economic impacts. These include possible impacts on government tax receipts. These are transfers from workers, consumers, and capital owners to taxpayers, and are effectively included in the figures presented above, which are defined in terms of total economic value. Taxes are a transfer of a portion of that value between parties — the distributional aspects (the extent to which part of these values are transferred to taxpayers) are not considered in detail.

There might also be impacts on local economic activity and development because of the non-use scenarios, but these impacts are expected to be limited.

There will clearly be an impact on international trade, with UK-based production being replaced partly or wholly by output produced outside the UK/EU. This is detailed in the previous sections and would be a combination of the lost output value from the applicants plus additional freight costs and the lost export values of goods and services from the customers trading values.

4.4.5 Compilation of socio-economic impacts

Table 7: Societal costs associated with non-use.

Description of major impacts	**Monetised/quantitatively assessed/qualitatively assessed impacts**
1. Monetised impacts	**£ [per year[1]] [Over x years]**
Direct business loss due to closure	£75.77M
Potential supply chain impact	£unknown
Social cost of unemployment	£1,720,096 over 6 year period
Cost of lost wages	£13,417,494 over 6 year period
Sum of monetised impacts	£90,907,590 +supply chain impact
2. Additional quantitatively assessed impacts	**[Per year] [Over x years]**
	Not applicable
3. Additional qualitatively assessed impacts	
	Not applicable

4.5 Combined impact assessment

Table 8: Societal costs of non-use and risks of continued use.

Societal costs of non-use		**Risks of continued use**	
Economic impacts (annual) Social impacts (over 6 years – declining value per year) ref table 4	£75,770,000 + £15,137,590	Monetised excess risks to directly and indirectly exposed workers (Annual values)	£118,220.08 £253,746.13 (higher bound sensitivity)
Off-shoring by supply chain (annual)	£unknown	Monetised excess risks to the general population	No risk to general population
Qualitatively assessed impacts	Not applicable	Qualitatively assessed risks	No direct emissions to the environment

Therefore, the total costs of the non-use scenario are estimated at £469.76M over the 6-year period from the implementation date. The added value lost, to UK GDP, by the supply chain offshoring manufacture would be significant (unknown value) over the same 6-year period. The total benefit of the non-use scenario i.e., avoiding the direct cost to human health as a result of exposure to Cr(VI) is estimated at £0.709M over the same period, with a value of £1.522M as an upper bound sensitivity.

It can be seen, then, that the costs of non-use clearly outweigh the benefits by several orders of magnitude.

Costs of non-use per unit of release.

Not applicable

4.6 Sensitivity analysis

The societal cost of continued use is severely increased in the calculations because of the WEL value used where results are reported as <0.025mg/m^3 and where reports have not been made available.

Assuming analysis levels to be similar to those reported as 'actual' values, the societal costs are expected to reduce by a factor of 10 as a minimum.

In this circumstance, the cost benefits of continued use increase by a significant factor.

4.7 Information to support for the review period

This group of applicants consider a review period of 12 years to be appropriate for the use of Cr(VI) in the coating of their product to create a coating which provides specific performance characteristics

The market for these products is dominated by Cr(VI) plated products because of their superior performance, in comparison to the available alternatives.

- The available alternatives to Cr(VI)-plated products have critical performance weaknesses which explain why they meet only niche requirements in this sector. While these critical performance weaknesses exist, any future lack of availability of UK-manufactured Cr(VI)-plated products in the UK will be met through imports of Cr(VI)-plated products (particularly from China), not through any substitution for non-chrome alternatives;
- As a result, until these critical performance weaknesses have been overcome, it will never be economically viable for the applicants to stop producing Cr(VI)-plated products in favour of these alternatives, and the non-use scenario will continue to be the closure of the applicants chrome businesses and with the additional risk of the supply chain (customers) relocating to a country outside of the UK/EU to an available geographic supply-base;
- The costs of these closures and relocation of the supply-base are extremely high and will continue to be so;
- In comparison, the risks of the applicants continued use of Cr(VI) are very low and will continue to be so. These risks will not be avoided in the non-use scenario, but simply shifted from the UK to another country outside of the UK/EU;

- Within the wider industry, and material suppliers, research into alternatives to Cr(VI)-based electroplating has been carried out for decades to address the existing performance weaknesses of alternatives, and it continues to do so. However, the performance advantages of Cr(VI) are very strong, and major innovations and developments would be necessary to overcome them. Industry has initiated joint research with academic groups in an attempt to address these weaknesses, but no significant success is expected within the foreseeable future;

- Even if a viable alternative of equivalent performance to Cr(VI) was to become available, it would still take several years to develop into a marketable product, to industrialise the production process, and to implement the necessary process changes for large-scale manufacture. These changes are expected to be highly costly.

- The conclusion of this assessment is that research and development efforts made in the past and ongoing efforts made by Industry have not led and will not lead to the development of a suitable alternative that could be available within the normal review period. The remaining risks are low and the socio-economic benefits are high (around 20 times), both estimated on a highly conservative basis, and there is clear evidence that this balance is not likely to change in the next 12 years. Taking this into consideration, the applicants argue that a `long' review period of twelve (12) years is appropriate.

5 CONCLUSION

Section 4.7 (above) details the reasons why the applicants recommend authorisation for continued use of Cr(VI) [chromium trioxide] and this authorisation to be granted with a review period of 12 years.

6 REFERENCES

1. BS EN ISO 6158:2018 Metallic and other inorganic coatings. Electrodeposited coatings of chromium for engineering purposes.
2. Application for authorisation for the continued use of chromium trioxide produced by the Chromium Trioxide Authorisation Consortium (CTAC) made up of the key producers and importers of chromium trioxide and wet process chemistry for electroplating.
3. ALARP – Health & Safety Executive principle – As Low As Reasonably Practicable. This involves weighing a risk against the trouble, time and money needed to control it. It describes the level to which the Health & Safety Executive expect to see workplace risks controlled.
4. Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating. A report produced by the German Federal Institute for Occupational Safety & Health (BAuA)