SUBSTITUTION PLAN

Legal name of applicant(s):	HAPOC GmbH & Co KG
Submitted by:	HAPOC GmbH & Co KG
Substance:	Chromium trioxide (EC: 215-607-8, CAS: 1333-82-0) and its aqueous solutions
Use title:	Use of chromium trioxide in solid form and its aqueous solutions of any composition to modify the properties of surfaces made of metal or plastic, with or without current flow.
Use number:	2

CONTENTS

TABLES

FIGURES

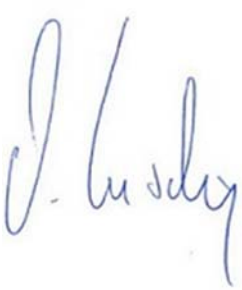
LIST OF ABBREVIATIONS

EOL	*End of Life (product level)*
OEM	*Original Equipment Manufacturer*
ABS	*Plastic Acrylnitrile-Butadien-Styrole-Copolymer*
HV	*Hardness Vickers*
PC-ABS	*Plastic Polycarbonate-Acrylnitrile-Butadien-Styrole-Copolymer*
R-values	*(Rmax/Rz/Ra) Description Roughness*
ROHS	
TRL	*Technology Readiness Level*
Zebra effect	*Differences in colour and function*

DECLARATION

We, hapoc GmbH& Co. KG in cooperation with VECCO e.V., request that the information blanked out in the “public version” of the Substitution Plan is not disclosed. We hereby declare that, to the best of our knowledge as of today (10.09.2020) 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.

Memmingen, 10.09.2020



M. Enseling (hapoc)

Dr. U. König (eupoc)

1. INTRODUCTION

In principle, the availability of a suitable alternative in general, which is not feasible for the applicant or his downstream users, is a de facto trigger for the submission of a substitution plan.

According to T. Öberg, the objective is not a hazard- or risk-based, but an ***effect-based substitution /1/***. In a commentary on an article by R. Löfstedt /2/ he explains that the approval procedure always includes a risk assessment as well as an impact assessment. Thus, the goal is a successful implementation with dues consideration of all the consequences.

In a further comment on an article by R. Löfstedt /3/ O. Renn states that an automatic application of the substitution principle without consideration of the consequences is not promising. Similarly, J. Gierling, MEP /4/ argues that a substitution can only be effective if relevant conditions are met and the process is based on sound science and a complete risk assessment. If substitution is rushed, regulators may also risk the process being ineffective at best and, at worst, causinge significant harm to human health and the environment.

At the same time, the European Commission on the promotion of substitution of SVHC substances /5/ states that, for successful implementation, it is necessary to promote capacity building and cooperation networks as well as R&D investment (EU and Member States) in sustainable chemicals and technological innovation (Action 5).

For this purpose R. Packroff compiles the following results of an BAUA event on 14.01.2019 /6/:

1. From the considerations of REACH:

   "An important objective of the new system to be established by this Regulation is to encourage and, in certain cases, ensure that substances of concern are eventually replaced by less hazardous substances or technologies, where suitable economically and technically viable alternatives are available".

2. Summary and conclusion:
   - For the substitution of Cr(VI) there are already promising solutions for some applications.
   - The development of alternatives is costly and associated with (entrepreneurial) risks.
   - Customer requirements and existing (product) standards make the use of alternative solutions difficult.
   - The transdisciplinary cooperation of science and practice is essential for successful solutions.
   - (Public) research funding must accompany substitution up to market maturity and acceptance.

Furthermore, a recent study by BAuA /7/ on possible substitutions of Cr(VI) comes to the conclusion that the final implementation in a successful substitution is no longer a technological

1 T. Öberg, Commentary on the Löfstedt substitution paper, Journal of Risk Research, 17.5 (2014), 565
2 R. Löfstedt, “The substitution principle in chemical regulation: a constructive critique”, Journal of Risk Research, 17.5 (2014), 543
3 O. Renn, Journal of Risk Research 17.5 (2014), 597
4 J. Girling, Commentary on the Löfstedt substitution paper, Journal of Risk Research, 17.5 (2014), 593
5 MITTEILUNG DER KOMMISSION AN DAS EUROPÄISCHE PARLAMENT, DEN RAT UND DEN EUROPÄISCHEN WIRTSCHAFTS- UND SOZIALAUSSCHUSS - Gesamtbericht der Kommission über die Anwendung der REACH-Verordnung und die Überprüfung bestimmter Elemente - Schlussfolgerungen und Maßnahmen, EU Kommission 2018
6 Informations- und Dialogveranstaltung „Perspektiven der Substitution für Cr(VI) – Funktionieren die Alternativen und sind sie bezahlbar?“, BAuA, Dortmund, 14.01.2019
7 “Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating”, BAuA - Federal Institute for Occupational Safety and Health, 1st edition 2020 Dortmund/Berlin/Dresden

problem but depends on the economic and market-oriented conditions of the companies concerned:

> *In summary, the development of alternatives for hexavalent chromium plating has made significant progress in recent years and significant market share in the area of decorative chrome plating has been gained. However, the user industry has still pointed out technical deficiencies of alternative methods especially regarding functional chrome plating, which are unacceptable for the respective applications. The practicability of a switch to alternatives depends on the respective requirements of the industrial applications, which have to be checked on a case-by-case basis.*
>
> *Within the scope of this project it became obvious that in general there are no one-to-one replacements that can substitute all intended properties of a chromium surface deposited from chromium trioxide. Therefore, substitution is often driven by overarching innovation objectives where a combination of effects, e.g. increased safety at work, resource-saving production, improvement of product properties etc., is targeted.*
>
> *Looking ahead it has to be noted that the revision process of the BAT document "Surface Treatment of Metals and Plastics" (European Commission 2006) regarding Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) will start in 2020. It is to be expected that developments regarding the substitution of chromium trioxide will also be considered.*

This is further confirmed by the European Commission's 2017 report "Impacts of REACH Authorisation" /8/. Various examples show that technological alternatives are available for special applications, but that these are only transferable to a limited extent.

The fundamental challenge of an implementation is therefore not only for the coating companies concerned. Support for this objective is required from all the organisations affected in the value and control chain, including the regulatory authorities and the possibilities of research funding.

The main task for a successful substitution and to avoid a "regrettable substitution" is the joint decision with the end customers. This is also because the products are in most cases overall systems that can only be described uniformly to a very limited extent.

1.1 **Requirements**

For hapoc's application, this means that the focus is on assisting the affected companies to evaluate technologies and implementation possibilities.

While the companies have to create the technological and economic conditions to meet their specific possibilities, it is the task of VECCO and hapoc to provide relevant information.

An important decision support is the study of the Lowell Centre of Sustainable Production from 2017 /9/, which is used by the European Commission and ECHA as a basis for discussion.

This study identifies the following points and requirements in the discussion on the implementation of a substitution plan as being relevant:

---

8 Impacts of REACH Authorisation - Final Report
EUROPEAN COMMISSION, DG Internal Market, Industry, Entrepreneurship and SMEs, Directorate D — Consumer, Environmental and Health Technologies, November 2017

9 Approaches for Accelerating Substitution under REACH and Beyond: Strategic Options Assessment;
J. Tickner, M. Jacobs, G. Howard, University of Massachusetts Lowell, Lowell Centre for Sustainable Production, 31 July 2017

- Increase knowledge and commitment of stakeholders at all levels, including EU and MS authorities, industry (different sectors and the whole supply chain) and NGOs, to provide a cultural basis for substitution and chemical innovation.
- Better link AoAs and substitution with activities at EU and MS level in the areas of innovation, recycling and global competitiveness of EU companies.
- Embed substitution thinking as a core approach to chemicals management in companies and authorities to accelerate the timing of substitution planning and the use of alternatives earlier in the processes of chemicals assessment and management.
- Improve coordination and networking between authorities and other organizations that can provide substitution support.
- Increase available resources to assist companies and others in decision-making on substitution.
- Increase the value and quality of assessments of alternatives carried out within the framework of the approval and restriction procedures and beyond regulatory programmes, through improved advice and training.

This study thus also confirms that successful substitution depends on the possibilities for implementation by the companies. They need knowledge and support from their customers, but also certainty with regard to the consequences of technological decisions, especially in respect to the availability of the substances required for substitution.

The wide range of applications of the hapoc application was decided upon several times within the procedure. In contrast to other applications, the applicant's focus is on the use of the substance. For example, no distinction is made between functional and decorative applications.

For this reason, we consider the first prerequisite for the preparation of a substitution plan to be the grouping of the applications (utilisations or clusters). The formation of clusters creates homogeneous groups, with comparable requirements for key functionalities and supply chains.

This substitution plan checks whether a plan is necessary or not in accordance with the SAGA concept on the basis of the subgroups. It is agreed that this is done on the basis of the subgroups and not on the basis of the individual company or individual products. Based on the conditions described above, the decision is mainly based on the implementation possibilities of the companies and how they can be supported in assessing their own situation in a targeted way. At the same time, however, common goals are set which have to be aimed for by the participating companies.

In the foreground is the evaluation and creation of possibilities for all companies to realize substitutions and at the same time to continue to exist on the market and thus survive.

All the discussions have shown that it is not possible to develop a uniform substitution plan for all applications and companies. The BAuA study clearly states that only a case-by-case assessment makes sense and therefore the specific concerns of the companies and applications affected must be the focus of attention.

The objective of the substitution plan presented here is therefore to enable the participating companies to develop plans for the replacement of Cr(VI) technology together with their customers.

To this end, criteria and implementation possibilities are developed, which the companies can evaluate with the support of VECCO / hapoc and then implement independently.

1. Specifications of the European Commission

In addition to the above conditions, the European Commission defines the conditions for implementation as follows:

a. Description of a substitution

- It must have completed the research status (not "in abstracto" or "in laboratory")
- It must be generally usable. Special applications or exceptional conditions are not considered suitable.
- It must be technically and economically feasible in the EU
- It must guarantee the production capacity of the component
- It must be feasible, i.e. it must be feasible under the given production conditions
- It must take into account the legal and factual conditions for placing on the market

b. Predefined criteria to be addressed

- Perspectives of the treated alternatives
- Evidence of other operators using alternatives for the use
- Information from the consultation or other sources
- Performance, market acceptance, etc.

2. Criteria for implementation by the companies in the value chain:

The central responsibility for implementing a possible substitution lies with the companies in the production process and their customers. For this reason, their possibilities must be considered first and foremost:

a. Determining criteria for implementation
- Business model:
  In all cases galvanic job coaters
- Customer structure and supply chain:
  The requirements are very different
- Information status of the customers:
  Many customers have not yet considered a possible change
- Delivery reliability:
  Companies must ensure the availability of products for their customers

b. Drivers for substitution:
- REACH Authorization Process
- Assessment of the suitability of possible alternatives in the context of an AfA
- New opportunities on the market
- REACH, not authorization process
- Financial savings
- Other EU regulations
- To implement known alternatives on the market
- Non-EU regulations

c. Obstacles to substitution
- Technically not feasible to meet user requirements
- Lack of "new" alternatives for testing
- Competitive disadvantages compared to those who continue to use the SVHC
- Lack of human resources to perform the investigations
- Uncertain acceptance of alternatives in the market

- Unclear economic costs of a changeover
- The cost of switching to an alternative cannot be passed on

3. Implementation criteria of the applicant

As the application groups together a large number of users, such criteria, which are comparable for all companies, are essential for the applicant's substitution plan:

- Identify use(s) or jointly evaluate establishments
- Compile availability of alternatives (technical and economic)
- Identify drivers for substitution and work out possible actions
- Carry out an extended risk assessment
- identify competition and competitiveness in the different economic areas (e.g. EU / non-EU)
- Compile and, if necessary, coordinate customer activities.
- Identify, plan and implement further necessary developments (R&D)
  (This is supported by the result of the REACH Impact Analysis /8/ that the main substitution activities of the companies consist of intensifying research and development).
- Develop investment opportunities or financing possibilities.

4. Resulting outline of the substitution plan

- Technology assessment and product suitability
- Technology development projects - intensification of research and development
- Customer contact
- Market acceptance
- Impact assessment or consequences and perspectives of substitution (see also guidelines of the European Commission
- Timeline(s)

1.2 Distinction between the basic applications of the present application

The application submitted by hapoc covers the following applications:

1. functional chrome plating - hard chrome plating
2. functional chrome plating with decorative character
   a. bright chrome plating
   b. black chrome plating
3. electropolishing
4. decoating
5. plastic pre-treatment
6. anodising (all alternatives special developments)
7. passivation (thin), incl. stainless steel colouring)

The following figure shows the distribution of the requested applications among the companies of VECCO.

In the meantime, the decoating and electropolishing applications are no longer used separately by the companies. The "decoating" application is increasingly integrated into the production process of coating. For this reason they are no longer considered in the present study.

Since, due to the structure of the application, all applications have been combined, the possible substitution plans have to be separated very carefully.

According to the European Commission's assessment, however, a substitution plan is also mandatory only for decorative-functional applications.

Within the framework of the discussion, however, we consider it appropriate to make a comparative assessment of the other applications on the basis of the criteria for decorative-functional applications and to describe possible substitutions on the basis of the implementation options developed there.

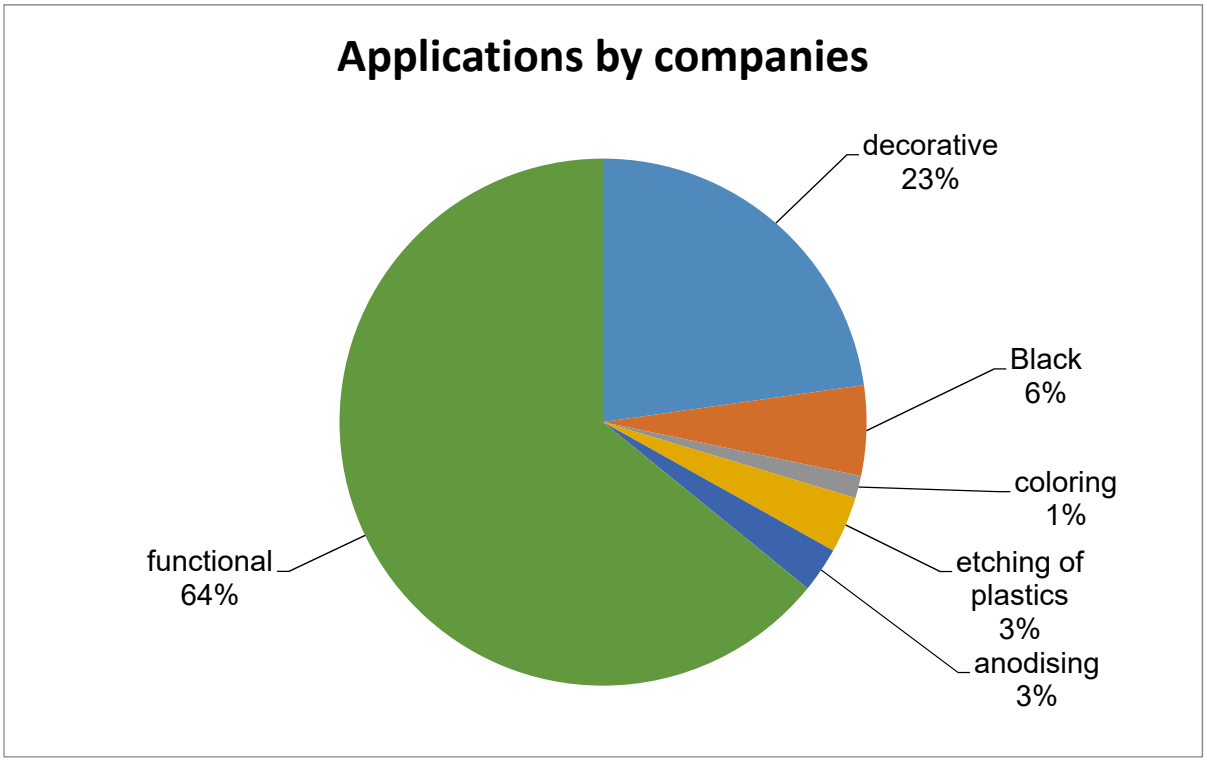


Fig. 1: Share of applications by companies involved

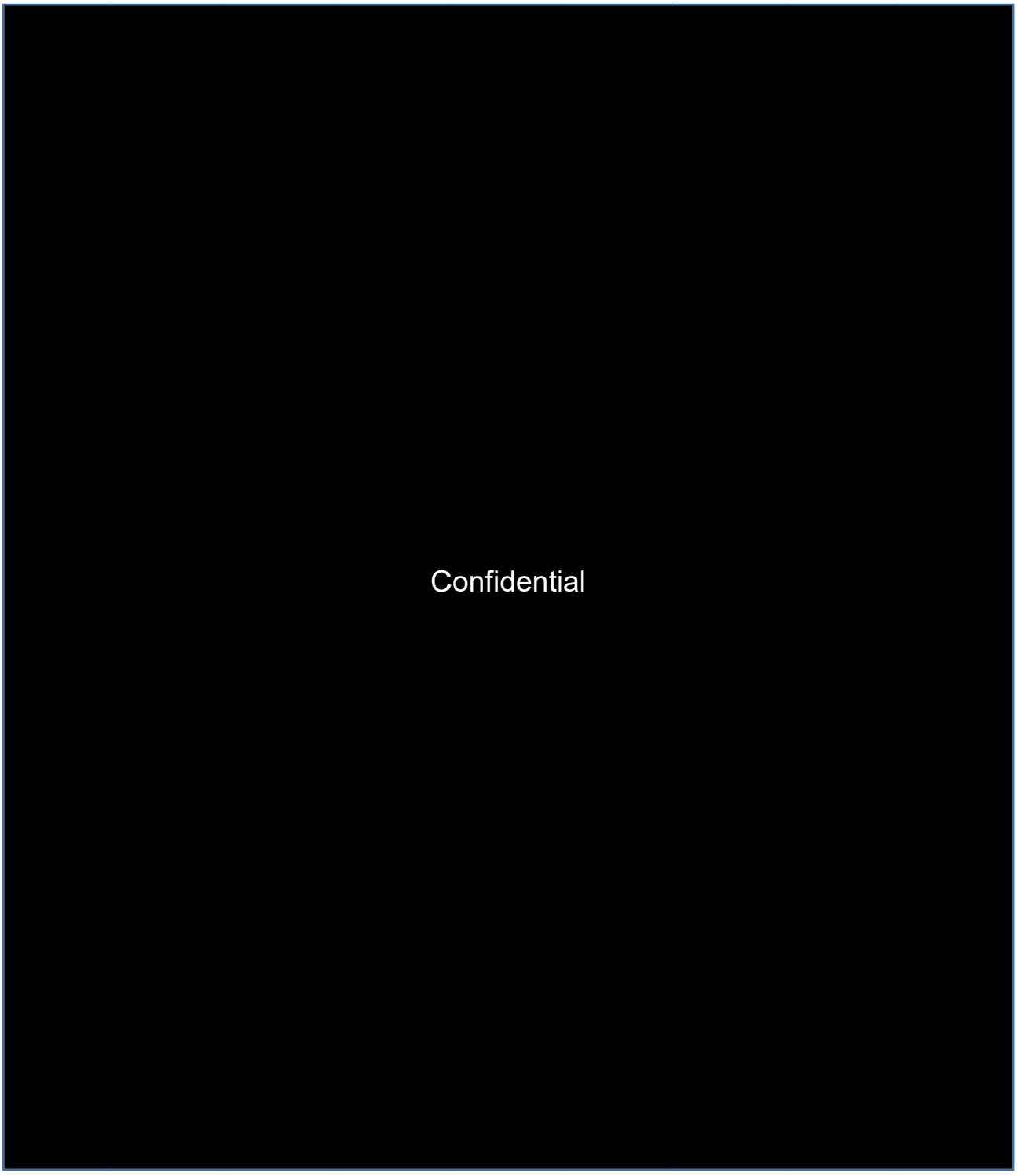
1.3 **Companies affected**

In order to underpin the scope of the considerations and the relevance of the groupings, only the establishments organised in the VECCO are taken into account.

Other companies may in principle join. They must undertake to comply with the conditions described in this substitution plan.

VECCO and hapoc are responsible for ensuring that the conditions are met.

The following companies support the hapoc application by name:



[redacted]

Confidential

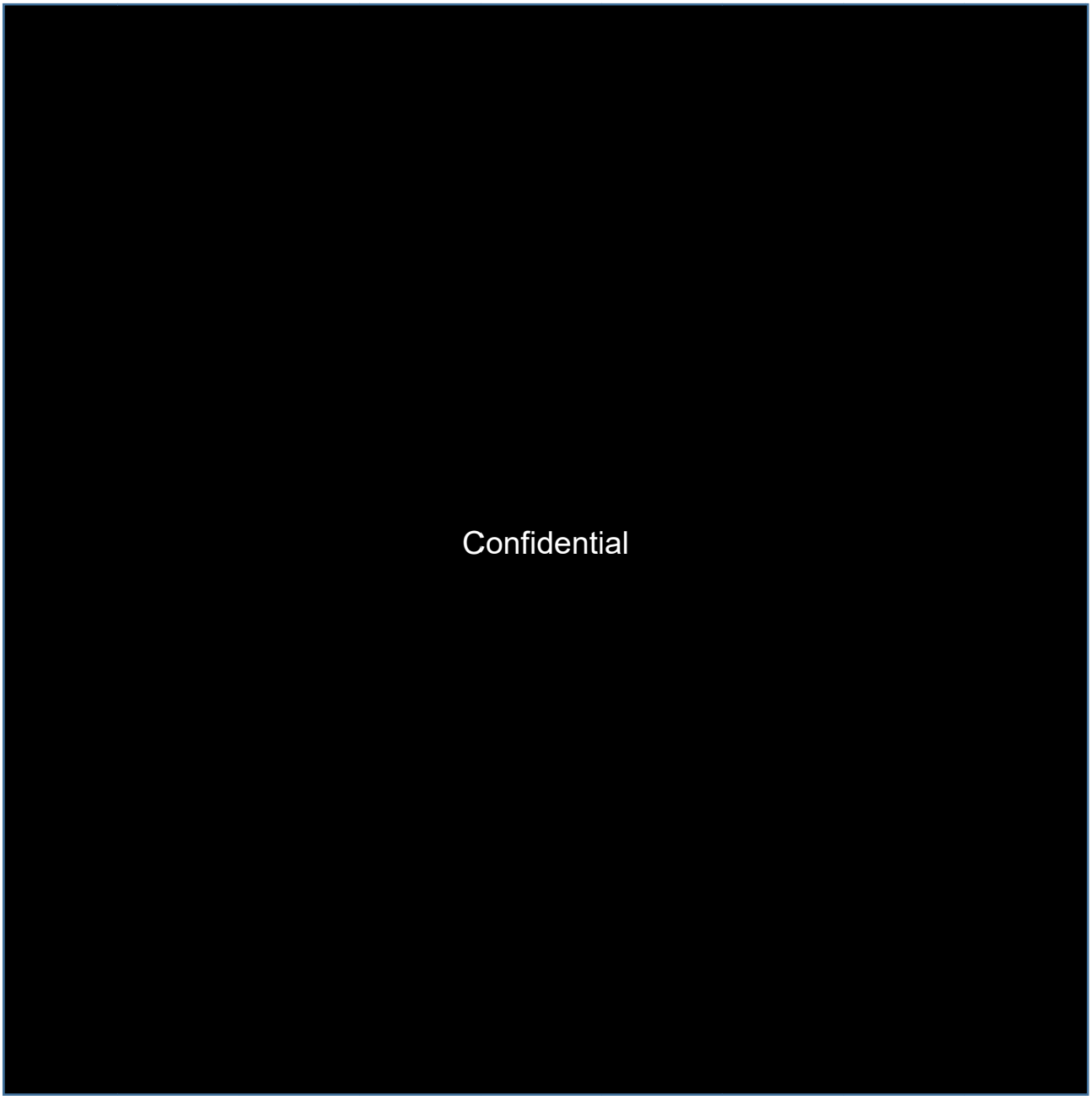


Table 1: Companies sharing the hapoc Afa

1.4 Criteria for a successful substitution

1.4.1 Basic thoughts

Substitution possibilities require a suitable grouping of applications. Criteria could include key functionalities, use in the value chain and customer requirements.

It is necessary to include customers along the value chain. Only they can provide meaningful alternatives in basic materials and design for their specific product, combination of partial products or service. The main challenge for successful substitution is therefore to include the value chain. Only if customers and end users are included can the substitution of Cr(VI) substances be successful.

Intellectual property (IP) management and the competitive situation can prove problematic. This must be taken into account in the discussions.

The main focus must therefore be on cooperation between all the companies involved, while at the same time giving the companies as much leeway as possible to implement substitution under their own specific conditions.

1.4.2 **Developed criteria**

For a successful substitution, the survival of the companies involved is essential. It must be achieved that the electroplating plants can secure their own activities.

This essentially requires cooperation with the customers. Since the end product chrome is not critical, not too many customers have yet considered substitution. This mainly concerns the mass market.

The following table summarises the parameters for successful substitution.

They must be integrated in a substitution plan.

Criteria	Relevance	Handling
Functionalities	Essential for SAGA/AoA	• Analysis of selected products
Technical feasibility for electroplating	Essential for survival	• Focus on galvanic processes: essentially Cr(III)
End use/product	Essential	• Can combine individual products/product groups into integrated applications
Substrates and substrate combination	Essential for end product / end use	• Composition of the design of the final product
Customer acceptance	Essential	• Cooperation with customers • Information for customers
Market penetration; EU / non-EU	Essential	• Essential if substitutions are marketable
Industries / Supply chains	Important	• Presentation of the variety of applications • Advantage of a wide product range
Number of products / capacity	Important	• To be generated
Product groups	Essential for grouping	• Generate from individual products

Table 2: Criteria for successful substitution

1.4.3 **Grouping**

Individual parameters must be combined with regard to the end use. Thus a combination of functionality, end product and market acceptance is important.

In all applications, further development requires support of the companies and their customers regarding technical developments and information collection.

VECCO / hapoc take over this task within the framework of the cooperative network approach:

1. regular information events
2. organisation of special discussion rounds / webinars
3. compilation of relevant technical information
4. assistance with projects
5. assistance with conversions

1. supply chains / sectors

Together with the companies, main use groups were identified. It has been shown that most electroplating companies are active in these groups.

On average, all companies have 3-5 main applications. These can be identified both from the number of products processed and from the share of turnover.

15 main categories/sectors:

1. food industry
2. defence technology
3. power engineering
4. automotive - machines/drive
5. automotive - interior/exterior decoration
6. textile
7. aviation
8. consumer
9. mechanical engineering / plant construction
10. plastics/packaging industry
11. sanitary
12. furniture
13. repair
14. medical technology
15. toolmaking

These can be divided into further specific sub-categories for individual companies (see also sec. 6.2 – Appendix 1).

2. technical criteria - substrates

In some areas, these "utilisations" can be linked by other overarching criteria. In the decorative sector, for example, in almost every category the importance of the substrates to be finished is essential.

On the other hand, in the field of black chrome, there are a large number of special applications which can only be grouped in accordance with the above categories to a limited extent.

Thus, the meaningful groupings differ strongly in the applications.

3. assignment or grouping / definition of utilisation

The particular challenge is therefore to divide the overall application into sub-groups and thus enable a transparent assessment of the substitution analysis. In our view, this is a major contribution to the future of the instrument of upstream authorisation.

a. Hard chrome

Hard chrome applications are very specific in the different supply chains.
Grouping by functionality or technical criteria is only possible to a limited extent.
Grouping in accordance to the main categories mentioned above has proven to be suitable.
The companies within these groups are characterised by comparable key functions, markets and supply chains. The key functions in these groups allow for an analysis of substitution possibilities, while at the same time providing a manageable level of detail.
This is illustrated in the following

b. Decorative bright chrome plating.
The discussion shows that the substrate issue is a cross-sector challenge. This criterion is therefore used to evaluate a possible substitution plan.
The technical challenge in, for example, the "Plating on Plastic" technology does not differ significantly between a product from the sanitary sector and the "automotive interior" sector.

c. Pre-treatment of substrate, especially plastics
The substrates to be coated must be activated in a suitable way for coating.
This is a particular challenge in the field of activation of plastics.

d. Black chrome plating
The large number of special applications available means that only limited grouping is possible. The end use has proven to be suitable.

e. Other applications
Special applications such as anodising or colouring are so specific in their use that a discussion only makes sense on the basis of the criteria listed in Table 2.

1.4.4 Resulting task – VECCO and hapoc

The parties themselves have but few possibilities to carry out the necessary technical developments. Information on possibilities is also limited (see also sec. 6.2 – Appendix 1).

Therefore, the focus will be on research and development projects in cooperation with the companies. These will preferably be carried out by the VECCO companies concerned, but are in principle not limited to them.

Knowledge of the situation of the companies will be ensured by regular surveys and monitoring. This information is jointly evaluated and made available to the companies.

Together with the industry journal WOTECH, experience reports on possible substitutions are prepared and published.

The reports are published in an annual compendium and also made available to the authorities.

The plan for successful substitution is to be divided into the tasks of the authorisation holder hapoc/VECCO and the tasks of the participating companies.

The main features of the organisational structure assign the task of supporting the holdings to the applicant.

In any case, it is necessary for a central institution to assume responsibility for overarching requirements, such as

- Description of the general work scenarios
- Organisation, implementation and analysis of measurement programmes
- Analysis of alternative technologies for substitution
- Support and advice for companies

hapoc and VECCO will take on these tasks. The current monitoring programme shows that hapoc reaches 100% of its customers and VECCO reaches more than 70% of its members. The target figure here is at least 90%.

This means that all the establishments eligible for hapoc approval are known. A broad representativity of the data is achieved by the other VECCO members (see list at the beginning of the substitution plan - Table 2).

1.4.5 **Resulting tasks – Downstream Users**

Based on the discussions, a company must carry out the following tasks in cooperation with VECCO and hapoc.

The companies are grouped together in possible clusters.

1. classification of products according to key applications
2. list the main products on the basis of their management systems, e.g. ERP systems and/or economic ordering systems.
3. grouping of the main products into portfolios according to their key functionalities.
4. allocation of the products / product groups to supply chains and the end user industry.
5. listing of by-products (less than 10% of sales) and classification of their functionalities.
6. decision whether the by-products are processed differently from the main products.

1.4.6 **Current activities of the companies – decided alternative for substitution**

For substitution purposes, electroplating companies concentrate on technologies that can be realised with the production processes and procedures available to them. As customers require metallic chromium, the most promising substitution for electroplating companies will be Cr(III) technology.

Only in special cases will other technologies be used in addition, usually in cooperation with customers. However, these are used as a supplement and should not be seen as substitutes.

1.5 **General applicability of alternatives**

1.5.1 **A note on the generic nature of the use application**

The applicant notes that SEAC has expressed a reservation regarding the generic nature of the definitions of uses submitted by the applicant. Whilst the applicant understands that any assessment of a larger group of applications is complex it is a reality of the REACH process that there are a lot of uses for Cr(VI) in industrial processes today. It is also uncontroversial that whilst these applications add value, substitution would be a good thing where possible.

The very heterogeneity of the applications render it entirely conceivable that for the same application – say decorative-functional plating – there can be one item for which an alternative technology works and another for which it will be unacceptable. Where for other authorisation substances the actual applications downstream were in most cases limited, this is not the case for Cr(VI). So some form of macro-assessment is required to determine whether an authorisation is justifiable. hapoc as part of its cooperative structure is the one who will be making efforts to substitute where possible as it will be present on the work floor.

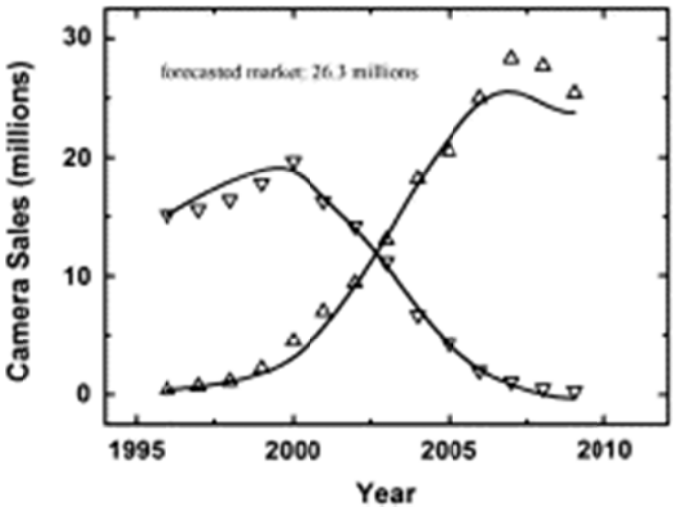
It is impossible for any paper exercise like an authorisation process to be 100% certain that all substitution is done as fast possible and is possible in all cases. What the process can do is to determine the basic validity of the need for the application, whether the substitution process is proceeding according to statistically verifiable curves /10/ and to hasten that process to its theoretical maximum by submitting the processes to authorisation.

1.5.2 **Uniformity of substitution processes**

The decline of certain industrial processes – of which technological substitution is merely a subset – follows predictable and uniform patterns. This conclusion was first academically published by

10 This is the key advantage of the analysis of Cr(VI) uses, there are enough applications to make statistically relevant examinations of the substitution data.

Walther Hoffmann in his book British Industry 1700-1950 /11/. The studies have since been repeated in various manners but the general conclusion is that substitution takes a rather uniform pattern. The output from a process starts to decline at an ever increasing rate until it levels off sharply. Then a relatively long period passes in which the final small percentage is maintained before the process disappears altogether.



As an example we can look at the sale of cameras compared to mobile phone camera enabled devices /12/:

This pattern is extremely typical for all forms of substitution. The S-shaped curve has been described in a variety of studies and several authors have attempted to coin a name for the process /13/. The question is what authorisation can do to hasten the process so that a change (where possible) is hastened to maximum effect. The challenge presented is not different from the owners, inventors or drivers of innovation and substitution who are convinced of the validity of their new technology but find a more or less unwilling customer base.

The example of cameras is telling because the substitution was driven by one of the most aggressive booms in technology introduction amongst consumers and supported by the largest corporations as well as social change. Despite all these assets to drive substitution the process still took 15 years and there remains a small irreducible set of cameras being sold that are not substituted by other devices. The SEAC should examine the reality of possible substitution of Cr(VI) applications according to this kind of chart on the understanding that the applications are a mix of consumer, industrial and very high end technology/military/aerospace applications. Evidently the standard chart would have a slope of the curve of substitution that could be sharper or less aggressive depending on the application.

There has been study about what factors can influence the pace of substitution and in particular how much of an improvement to a standard curve can be made. In this context SEAC should consider that government, like experts, authorities, media and so forth is just a part of the social context that can drive substitution and innovation. Certainly it can play an important role but it cannot accentuate the slope of the substitution curve in more than a limited fashion. This follows inter alia from a study of 2006 /14/ which gave the following chart:

11 Oxford Basil Blackwell, 1955.
12 Technology substitution and innovation adoption: The cases of imaging and mobile communication markets, L. Miranda, C. Lima (Technological Forecasting and Social change, Volume 80, issue 6, July 2013 pp. 1179-1193). http://www.sciencedirect.com/science/article/pii/S0040162512002880
13 A well-known one is the Bass Model; *Bass, Frank M. (2004). "Comments on "A New Product Growth for Model Consumer Durables": The Bass Model"*
14 Dynamics of Social Factors in Technological Substitutions , Brice Dattée, Henry Birdseye Weil – MIT Sloan School of management Working Paper # 4599-05

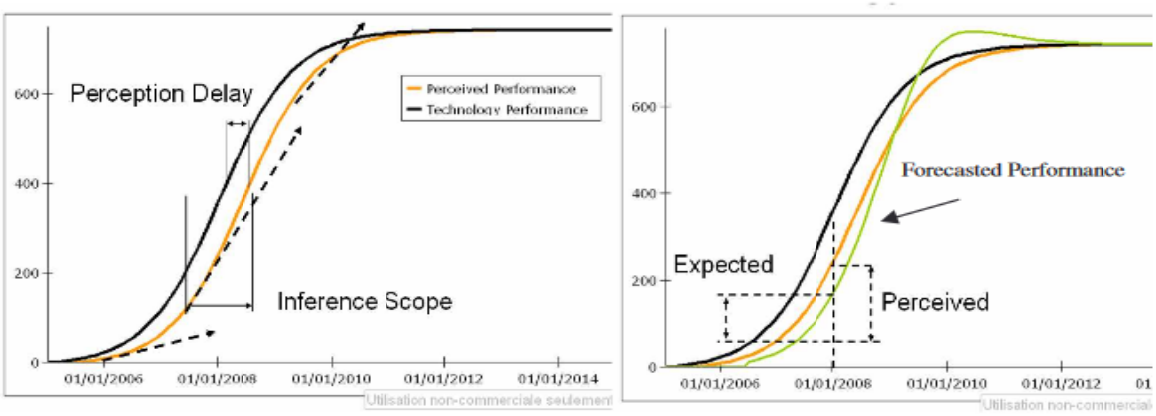


Figure 1: Systematic Forecasting Error of Linear Extrapolation

Without going into detail – what government and other actors can do is to raise the slope of the amber coloured line to the level of the black line. This means that in the first stages it can have a major impact on the substitution of technologies, because the slope of the take-up will at first be very flat. It could be sharper with additional support. Then there is a rather stable area of improvement that can hasten conversion or adoption by a factor of 10% (a few years mainly) after which the possibility and ability to effect change level off dramatically to near zero. These remaining applications being the irreducible minimum which, for whatever reason, find the substitution impossible.

1.6 **Realisation**

There is agreement that any single possible substitution should take place as soon as possible, but this is not possible in every market and in every industry at the same time. The resulting differences in time are a major challenge in implementing substitution.

However, it must be ensured that the process of implementation is as rapid as possible. hapoc, as the holder of the authorisation, can play a key role in driving this process forward and overcoming individual resistance (many people are conservative about change), sharing knowledge and pooling resources to achieve the optimum curve.

As our detailed analysis below shows, there are some applications that can be substituted, some that absolutely cannot and a great many of them somewhere in between. This is a dynamic process, which is described fairly accurately by the theoretical S-shaped curve for substitution. For this reason, the most logical scenario of non-use is a scenario of gradual change - the longer the approval period, the lower the undesirable effects will be if the substitution curve does not take sufficient account of the possibilities of the substitutable technologies.

2. FACTORS AFFECTING SUBSTITUTION

2.1 Reference to information of the application submitted and further information provided

A first analysis at product level was carried out by the applicant in the reply to the questions of 31.07.2017.

In this document, some examples were also given for which the substitution was not successful.

Based on this information, VECCO/hapoc has, as part of the substitution plan, continued a regular survey of its members to evaluate current developments and their feasibility. The results are published and serve to evaluate the status quo.

In the meantime, this is also mainly used to inform customers about the status of development.

2.2 General significance of the VECCO for successful substitution

The VECCO's cooperative approach is an essential element of the substitution plan.

Within the framework of the joint work, the companies can contribute their specific problems and opportunities in order to benefit from other solutions.

At the same time, the information for customers can be shared.

2.3 Specific economic situation of VECCO companies

In addition to the technological availability of the alternatives, their availability on the market is relevant for the job-coaters to implement.

Only when the processes have been sufficiently tested and are available on the market can the implementation conditions be planned.

If the companies want to implement a conversion in the next two to three years, it can be assumed that the availability of different technologies will be insufficient.

Furthermore, the companies' own economic situation is relevant for the implementation. For substitution, the companies must have sufficient investment funds at their disposal on the one hand, and on the other hand planning security that the modified products will be in demand on the market.

If these conditions are not present for an individual company, it can be assumed that the alternative is not generally available under its specific conditions.

As a result, VECCO will work together with the company to find a solution for implementation.

2.4 Extended technological analysis

The hapoc AfA describes a wide range of applications of chromium (VI) in various industries and supply chains as described in the previous sections.

The different uses of the present upstream application differ considerably in the technical requirements. Any substitution approach must take this fact into account.

The technical conditions and differences are taken into account by grouping those uses in so called "utilisations". The technical conditions can vary considerably depending on the utilisations.

In this substitution plan, we understand utilisations as subgroups of applications that allow a specific substitution analysis in homogeneous groups without getting lost in too high a level of detail.

In accordance with the SAGA concept "Suitable Alternative General Available" we examine the substitution situation of the respective use on the basis of the groups described in sec. 1.4.3.

Technically, the evaluation of the applicability can be based on the classification of the Technological Readiness Level (TRL) /15/ (Fig. 2).

The evaluation of the implementation is based on the evaluation criteria described in sec. 1.5. On the basis of S-shaped substitution curve, the timeline and the effectiveness of the actions for implementation can be described. The details of the evaluation can be found in section 3

After the introductory consideration in section 1 and the definition of the EU Commission, the focus is placed not only on safety but also on practical feasibility for the user.

This consideration eliminates all technologies that are not yet in the development stage ready for series production. In accordance with the TRL concept, promising approaches will continue to be observed.

The analysis is based on the studies currently available and discussed, in particular the BauA study "Survey on technical and economic feasibility of the available alternative for chromium trioxide on the market in hard/functional and decorative chroming" /7/.

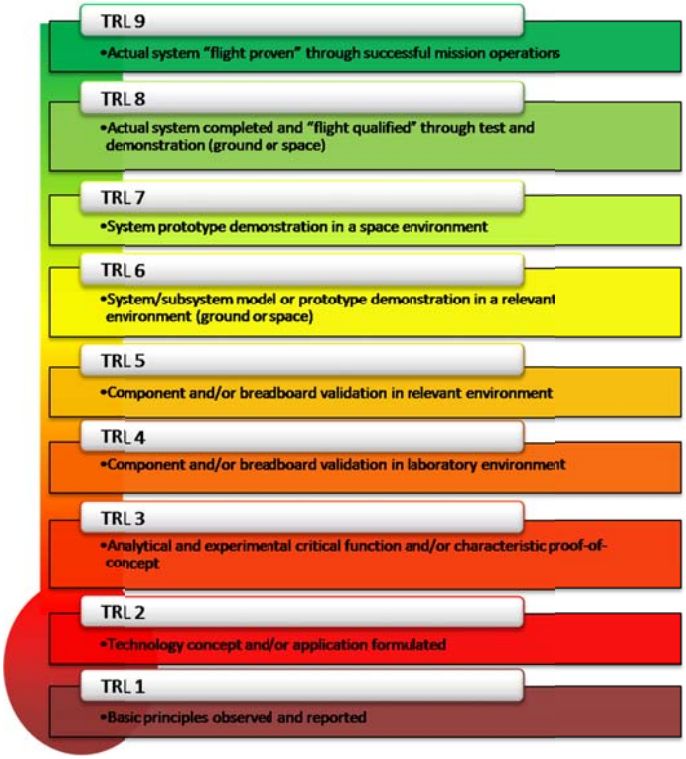


Fig. 2: Technology Readiness Level (TRL) according to NASA

This study shows that in many specific cases of individual applications different technologies are available and already in use. However, this is very product-specific and cannot be generalized, which the BauA study also confirms.

15 /https://www.ptj.de/lw_resource/datapool/systemfiles/cbox/2373/live/lw_file/definition_des_technologischen_reifegrades.pdf bzw. https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

The described technologies reach their limits in special applications because the required key functionalities are very different. In these cases, a successful substitution requires significantly more effort.

However, it is possible to define criteria that apply to all industries in individual cases and that can be further developed for all applications in the same way. This is undoubtedly the case for the decorative-functional sector.

2.5 Extended Economical consideration

In electroplating technology there are some special features and barriers that must be highlighted. Many companies are active with one technology in several utilisations (technical applications). For example, a company produces „Plating on Plastic“ for automotive interiors and engine valves. A substitution plan has to be drawn up for both utilisations which are technologically and economically very different.

Depending on the alternatives, the company has to decide which technology to choose. Most electroplating companies therefore choose electroplating processes for substitution, with a focus on the Cr(III) processes.

Non-electroplating processes will only be considered by the Vecco/hapoc companies in very individual cases. Processes such as salt bath nitriding are connected with a high organizational and financial expenditure (investment costs of approx. € 3.5 million for salt bath nitriding or PVD plants). A realization is only possible together with the customer.

For the electroplating industry a clear trend towards "related technologies" such as Cr(III) coating has emerged in our webinars. The technologies are known and the periphery exists in the companies.

In this substitution plan, hapoc concentrates on the galvanotechnical alternatives, primarily Cr(III) technology. Other technologies that are relevant in certain niche-uses (utilisations) and have TRL9 are presented in examples of project plans in section 3.

Traditionally, the SME job-platers in Europe are very loyal to their location and their business models have always been regional. Larger companies and corporations often think and act more globally and consider relocations to non-European countries. This risk is very real for these companies.

We therefore assume that market concentration and a trend to bigger companies with more financial resources will end in plant closures and job cuts in Europe.

The main challenge is the acceptance of the new technologies in the industries and supply chains affected. In the following, the steps required for successful substitution are described from the perspective of the active electroplating-companies.

1. Market Acceptance

An essential requirement for successful substitution is the acceptance of the companies' customers. The job-plater is in a difficult position, since in some cases the exact function of the product is not known even to the customer.

There is a risk that substitution takes place without the involvement of the coating companies and that the companies cannot survive. However, it is also apparent that existing supply chains and long-standing customer-supplier relationships are better able to resolve this problem.

The manufacturer and thus the person responsible for the product must be involved in this process. Here, communication must be massively strengthened. A joint strategy using the possibilities of the VECCO association can make a significant contribution to this.

hapoc has launched an innovation platform together with Vecco e.V. In this network, necessary R&D work can take place with the involvement of the end customer and other interested parties (for details, see 6.2 - Appendix 2).

Due to the current discussion regarding sustainability and recycling, the manufacturers of products are increasingly and actively looking for solutions which secure resources.

Some frequently mentioned aspects are as follows:

- **Appearance of product value:**
  In the consumer sector, quality is particularly important in the high-price segment (white goods, furniture). In the low-price segment, the willingness to sacrifice quality aspects is supposed to be higher.

- **Economic areas EU/non-EU:**
  The requirements vary between EU and non-EU economic areas. In the non-EU economic area, the quality of the Cr(VI) chromium layers is absolutely required. Any reduction is not accepted. Due to the competitive situation, customers take their business elsewhere if the requirements cannot be met by the job-platers.

- **Combination of partial products:**
  In most cases the final product is composed of different partial products. Those partial products consist of different substrates. In the end, all the individual parts must meet the same conditions with regard to functionality and appearance. In the sanitary sector, a uniform appearance is vital despite the variety of substrates, e.g. Zebra effects (striped texture) are not acceptable.

- **Regulatory conditions:**
  Medical technology, drinking water, safety engineering etc. determined by laws and local regulations

- **Overall processes:**
  In general, the focus must be on global implementation. Often chrome plating is only a part of the overall process, but is firmly integrated in the process development.

2. Customer involvement / Customer interest

The end customer’s position partly dictates the acceptance in the overall market. This is necessary for the industrial implementation. Currently there are only few discussions with customers about substitution, but the trend is increasing.

Enquiries revealed that customers were unable to specify their exact requirements. Some claim to withdraw from the EU economic area. At the same time, the need for a change in behaviour and planning is increasingly seen.

Some customers only request proposals from the coaters when their end-clients ask for them. Here the legal situation or supply chain compliance is important.

Sampling is carried out by the coaters in various ways and presented to the customers. However, these do not currently decide on changes. The reason is often that their customers do not name their applications either.

In terms of customer relations, the situation is comparable in all applications:

1. In the end-consumer segment (e.g. furniture, sewing needles, etc.) the end customer / consumer does not care what the product is made of. The technical properties must be given. He buys what is offered by the manufacturer.
2. In some areas (e.g. automotive) innovation often fails because nobody wants to take responsibility for the change process. Thus innovation is blocked at an early stage.
3. In principle, increased activity of R&D into chrome substitutes can be observed.
4. Job-platers must be active, otherwise they are not involved in further development.
5. Companies participate in research and development. The problem is the existing resources.
6. At the same time, it was pointed out that information on the development topics may not be shared due to existing confidentiality agreements.
7. Customer contacts must be intensified as a consequence. High quality in the EU must be demonstrated, but this can only be done in cooperation with the customer.
8. There is a risk that other companies and branches in the supply chain will be affected if they have focused on Cr(VI) technology during the product development process. By looking at the combined end product there is a risk that the end product as a whole will be lost for the European Economic area.

3. Product variety

Many member companies of the hapoc consortium operate the business model of the job-plater. In practice, the business model is characterised by a strongly fluctuating product portfolio. The number of individual products ranges from a few hundred to 10,000 different articles per company.

Individual companies have both functional decorative and functional applications. The possibility of subgroups / utilisations as we have defined them in this substitution plan enables the companies to present their respective specific company situation.

In this way, the diversity of the industry is reflected and a proven business model is brought into line with the requirements of REACH. In our view, this is an important contribution to the future of upstream authorisations and the only alternative to a wave of individual authorisations.

As the trivalent electrolytes are very sensitive to entries of metals (Cu and Zn), the effort required to clean the Cr(III) baths is very high.

At the same time, for an economic production, several components, which have been coated in differently managed Cr(III)-plants, have to be combined for the final product (e.g. fitting body, outlet, handles). Differences in colour and function must not occur (Zebra-effect).

Economically, this control of the end product requires a high effort, which is only partially financed by the customer.

The customer needs the guarantee that their products can be processed quickly and reliably. The production capacities required must be taken into account.

When developing the end products, the alternatives must take into account aspects of recycling and sustainability. For the substitution plan this means an extended risk analysis with regard to these points.

4. Operational implementation in the companies

The main challenge is the organisation of the change-process and the precise and reliable planning of the subsequent production. The customer's willingness to give an acceptance guarantee is also mandatory. The financial effort regarding Cr(III) is deemed critical but feasible.

The companies have made various attempts with the Cr(III) coating system, both in-house and in cooperation with e.g. chemical manufacturers.

For example, fitting components for the sanitary industry have been coated and analysed using various test procedures (salt spray tests, layer thickness tests, optical tests, cross grid slot tests, etc.)

- An increasing number of companies are dealing with the conversion to, mostly towards Cr(III) technologies. The estimation of the timeline for successful substitution ranges from 1 year to 3 years if the technical conditions are clarified and the customers go along with it. Estimated costs (no new building): about € 150.000 – 200.000
  The decisive factor is acceptance by the customers. This must be guaranteed before planning.

- Companies which only work with one production line need customer security, because they cannot produce for several months whilst the production-line is in the refit-process.

- The main challenge is the organisation of the changeover and the exact and safe planning of the subsequent production. Furthermore, the willingness of the customer to give an acceptance guarantee is necessary.

- In the hard chrome sector the decision to implement an alternative technology is difficult. To replace hard chrome, a typical job coater needs 2-3 different alternative technologies. This is not financially feasible.

- An important decision criterion for the implementation is the financial possibilities. Here a support from public institutions is necessary for SMEs.

5. Future Application / Barriers to realization

In summary, the following points must be taken into account for a successful substitution plan:

- The end-use is often not known even to downstream users.

- An offer can only be made if the use is known. Often, however, reference is only made to a quality standard, which only describes the detail requirements to a limited extent.

- Not only the relocation of operations to the non-EU economic area but the relocation of orders from the non-EU economic area are both critical. The high quality standard in the EU has to be proven, but this can only be done together with the customer.

- Customer contacts are essential. These are taking place and must be intensified as a result of the substitution plan. Customers must demand and accept the coatings and the new technologies.

2.6 Procedure for implementing the substitution plan

Following the discussions above, our procedure for drawing up the substitution plan is described below.

It is based on the presentation of the grouping of uses to ECHA in April 2019 (for details see sec. 6.2 – Appendix 1)

The product portfolio is defined on the basis of recommendations for the use of key functionalities. Each product is classified in these functionalities and thus the use of alternatives can be analyzed and evaluated in a first approximation.

Since the number of products is very large the products will be grouped according to functionalities as recommended.

The analysis of the alternatives from the groups defined in this way is carried out to adjust the number of products (applications).

This has resulted in the following steps, which are to be considered in terms of a timeline for the substitution plan

1. **Step 1 – Identification of key applications**
2. **Step 2 – Identification of key functionalities**
3. **Step 3 – Identification of product portfolios**
4. **Step 4 – Improved evaluation of product functionalities for substitution by key alternatives (reference BAuA Study /7 /**
5. **Step 5 – Definition and selection of further necessary R&D developments**

2.7 Key application - decorative-functional

2.7.1 Description

Decorative chrome plating refines components by means of a uniform and stable chrome layer. The main requirements are an attractive appearance and sufficient corrosion protection. Haptics with a metallic appearance and value are purchase criteria for end-customers and manufacturers. Depending on the use, the requirements must be supplemented. Durability is important, but not as critical to the system as hard chrome plating is. However the way of handling and care of the product is very important and has an impact on the value (perception) of the end product.

The applications are varied and often the functional aspects also become important. In general, durable goods or products of higher value are chromium plated. Typical requirements of a high value are durability, resistance and sustainability. Often a combination with other high-quality materials is used. The decorative-functional coating generally has a wide scope for possible alternatives or substitutions.

1. Technical requirements:

Function	Assessment / Necessity
Certification	Chrome-plated parts must be tested and qualified for the intended use
Corrosion / Wear protection	Durability
Biocompatibility	Lack of reactivity with biological environments
Free of porosity	Porosity would impair function in the long term
Visual appearance/design	Quality aspect (increases the long-term value of the product)
Durability	Simple and sustainable care of the products
Functional cumulation	Combination with other parts of the end product

2. Available technical alternatives

In the case of decorative-functional chromium plating, the following technologies are mentioned as "generally available" and thus feasible alternatives:

- Cr(III) process
- PVD
- Painting
- Application of Stainless steel

The technologies are technically available and can be described by a TRL level of 7 or higher, i.e. they are generally applicable.

Risks can be identified in all cases. By using them, the CMR risk can be reduced by using the alternative technologies so that the basic availability is confirmed.

3. Areas of Applications / utilisations

Comparable substrates and technologies are used in all of the applications described below. However, some areas such as medical technology, electronics and optics are subject to special requirements.

General requirements:

- Automotive
- Furniture industry (especially metallic substrates)
- Sanitary
- Printing industry
- Shop fitting
- Music industry
- Office accessories
- Consumer electronics
- Domestic appliances (e.g. ovens) and accessories

Special requirements

- Medical Technology
- Electrical industry / electronic components
- Optical industry / photo industry
- Closure, shutter and security technology

2.7.2 Extended Analysis and updated AoA

- Cr(III) technology
  The most promising alternative technology is the Cr(III)-based process, which has made great progress in recent years. However, various developments still need to be carried out for a broad implementation in the electroplating industry.

- PVD
  PVD is only applicable under special conditions. Both capacity and coating properties such as abrasion, corrosion protection or adhesion are often not sufficient.
  Special adapted techniques are possible, but very expensive

- Painting
  Painting is applicable in some special uses but does not achieve the metallic gloss often required by customers. The combination of PVD with painting is successfully used in special areas (Chromoptics - Ropal), but has only found a limited number of application.

- Use of Stainless steel
  Stainless steel is used in high price segments. Dental tools are therefore increasingly made of stainless steel. Stainless steel is also increasingly being used for high-priced household appliances. The costs are estimated to be 3 - 5 times higher.

2.7.3 Decision to implement Cr(III) technology

1. Assessment or activities of the companies

- Cr(III) is considered a realistic alternative
- PVD and painting are not considered promising.
- Exchange of electrolytes possible. Change-Management is considered promising
- Substantial development is necessary for different substrates.
- There is interest in joint R&D initiatives

but:

- Substitution plans are also being drawn by customers without involvement of the job-platers. Chrome plating is only included in the planning as long as the Cr(VI) process can still be used. New products are no longer based on chromium plating.
- Individual authorisations should be reconsidered for uses that are too special.
- Many plants will probably close down when Cr(VI) is no longer possible. This assessment is independent of the possible alternatives and is based on the individual development possibilities of the companies (see also analysis Ch.2.3)

2. Pending technological aspects Cr(III) technology – R&D Needs

Although the Cr(III) technology is promising, several developments are still necessary:

- Colouring:
  Will be more reproducible, but not yet definitely resolved. Plating on plastic is deemed a foreseeable success.
  In the range of higher temperatures, e.g. ovens, the stability is mandatory. No satisfactory results are known for this yet. The possibilities largely depend on the substrate

- Properties of the chrome layer:
  Tribological properties like abrasion or adhesion as well as corrosion protection properties are not yet sufficient. The composition and structure of the chromium layer is not yet clearly reproducible. Other substances (metals) are often incorporated which influences the property ot the coating.

- Stability of the layer - abrasion and scratch resistance:
  The coatings must guarantee typical maintenance behaviour of the end customer. Stability against chemical care products and resistance to abrasion and scratching are necessary to provide mechanical treatments.

- Substrates to be coated:
  Here lies a key problem. While plastic substrates can be successfully coated in the foreseeable future, metallic substrates are still difficult.
  - Iron-based components contaminate the electrolytes with Fe ions, which can be incorporated into the layers and have a significant impact on the deposition kinetics.
  - Non-ferrous metal-based substrates cannot yet be coated with an adhesive coating.
  - No relevant findings are yet available for coating die-cast parts.
  - No relevant findings are yet available for coating aluminium alloys..
  - The combination of different substrates necessary in some areas (e.g. sanitary industry) is currently not reproducible (Zebra-effect).

- Hollow part areas:
  Currently, Cr(III) technology is not suitable for coating hollow metallic parts due to the reaction kinetics. The main reason for this is, on the one hand, the insufficient subsequent transport of Cr(III) and, in the case of metallic materials, the concentration of corrosion products such as Fe ions, which disturb the coating process.

- Pre-treatment (see sec. 2.8 for details).
  Various substrates require oxidative activation, either to roughen the surface (plastic) or to activate or cleaning (die-casting) with Cr(VI). No alternatives are available here yet.

- Approval:
  As the products are often used for a very long time and the characterisation is done by corresponding standards or requirement profiles, the new systems have to be checked for compliance.

3. Pending aspects Cr(III) technology related to production engineering- R&D needs

The industrial implementation requires a higher demand on production.

- Maintenance requirements (electrolytes)
  Due to the risk of contamination with Fe ions, maintenance such as analysis and cleaning of the electrolyte is much more demanding.

- Development of additives, e.g. complex stabilisers
  Adapted chemicals are necessary for stable production. At the same time, these must not pollute the environment and must be degradable in wastewater treatment plants.

- Coating capacity - Cr(III) is slower
  As the coating process is currently not yet as fast, the production capacity must be adapted. This is accompanied by the development of suitable electrolytes.

- Waste water treatment / environmental aspects
  The Cr(III) technology requires complex waste water treatment as the electrolytes require many additives such as complexing agents. The additives stability required can lead to complex degradation products, which are critical for the environment and additionally burden the wastewater treatment plants.

2.7.4 Implementation or development

Investigations are already ongoing in many areas to apply Cr(III) technology and other processes. However, there is only limited cooperation between the coaters and their customers.

Technology development in the application areas:

- Tools:
  Initiatives of the tool association are being used

- "White goods" - household appliances
  No result yet due to the diverse requirements for design and functionality. The use of stainless steel is occasionally considered. It is estimated that the products become more expensive by a factor of 3 - 5.

- Cookware:
  Costly due to individual design issues, currently no solution.

- Sanitary:
  Due to the variety of additional regulations (drinking water, food, waste water, biocompatibility) there is no solution at present. At the same time, the demands of the end consumer in terms of design and durability are very high, especially in the high-price segment (product share about 20%, but significant share of sales).
  The challenge is the parallel use of different substrates - plastics, ferrous materials, non-ferrous materials (bronze, messing) etc. Here, colour differences are clearly visible (Zebra-effect).
  In addition, there are different customer requirements that need a variable coating system.
  In principle substitutions seem possible in principle but it requires further development in the area of substrate variation.

- Medical technology/Aerospace/Security technology:
  The search for safe coatings is continuous, a substitution of chrome from Cr(VI) electrolytes is currently not possible

- Repairs:
  Due to the existing systems, it is currently not possible to replace the chrome plating. The thickness of the Cr (III) coatings is not sufficient for the rework-process (e.g. grinding).

2.7.5 **Possible Groupings**

The discussion leads to the distinction between substrates.

In the end uses, all substrates are used equally.

1. Plastic
   a. Pure
   b. Combination
2. Steel / iron
3. Other metals
4. Qualification of the final layer: colouring, polishing, etc.
5. Combination of substrates
6. Repairs / Spare parts

The following compilation of the discussions above makes no claim to completeness due to the wide variety of utilisations.

However, it will be updated in the context of further developments for substitution and serves as a basis for the IT-supported database.

Substitution possibilities decorative-functional

Description					Evaluation				Substitution
Grouping		Utilisation	Details	Requirements	Alternative	Experiences company and customer	Barriers	Challenges for developments	Substitution possible?
Group 1: plastics		Automotive		- adhesive strength - Colour - abrasion	Cr(III)		- Product variety -substrate variety		yes
		Consumer		- adhesive strength - Colour - abrasion	- Cr(III) - paint		- Product variety -substrate variety		yes
		Sanitary		- adhesive strength - Colour - abrasion	- Cr(III) - paint		- Product variety -substrate variety		conditionally
Group 2: Steel / Iron									
		Medical Technology	surgical instruments	- abrasion resistance - anti-reflection	- PVD - stainless steel	- Not abrasion resistant on joints - Special applications possible		- abrasion resistance - no reflection	no
		Medical Technology	Dentist tools	- Abrasion resistance	Stainless steel	partially converted			yes
		- safety engineering - Aviation.							no
		furniture		- abrasion resistance - colour	Cr(III)		- Product variety - capacity		conditionally
		Automotive	Exhaust pipes, covers, engine components etc.	- corrosion protection - Tarnish protection - thermal stability	- Cr(III) - PVD			PVD in the high price range No standard PVD	conditionally
		Pliers / Tools		- adhesive strength - Quality cutting edge		Tests by Professional associaton			no
		Sanitary	- fittings - pipeline	- drinking water stability - Food safety	- Cr(III) - Lackierung		- Product variety -substrate variety		conditionally
		Cookware	edge of cookware pots	- corrosion stability - Abrasion resistant - Temperature stable	Cr(III)	- attempts made - Not corrosion resistant		Experience enamelled cookware: experiments with Cr-II extensive changes necessary - Insufficient corrosion resistance - Insufficient appearance of the pouring edges - Dwell times in the Cr-II bath significantly longer: problems with the overall cycle - Long-term tests on the resistance of the chrome layer are pending	currently no

Table 3: Conditions of substitution decorative functional – part 1

Substitution possibilities decorative-functional

Description					Evaluation				Substitution
Grouping		Utilisation	Details	Requirements	Alternative	Experiences company and customer	Barriers	Challenges for developments	Substitution possible?
Group 3: other metals									
	Zinc die-casting	Sanitary	- closures - Fittings	- abrasion resistance - colour	- Cr(III) - paint	none / rudimentary	- Product variety -substrate variety	Problems with direct chrome plating Possible with underlying nickel	no
	Non-ferrous metals / alloys	Sanitary	- closures - Fittings	- abrasion resistance - colour	- Cr(III) - paint	Reference to standards	- Product variety -substrate variety		conditionally
	Aluminium	Medical Technology	Endoscopes	- hardness - sterilisability	PVD Cr(III)	none	not specified, no release		no
Group 4: Qualification final layer									
	Coloring	various spectral colours		- adhesion - homogeneous layer - increased corrosion resistance - optical upgrading	Cr(III)		- Thermally stable - Colour stability - No oxide layer possible		no
	Polishing			- adhesion - homogeneous layer					not known
Group 5: substrate combination									
	"white" ware consumer goods	Consumer	Home appliances	- abrasion - appearance - cleaning	stainless steel Cr(III)		- Thermally stable - colour stability - costs		no
		Sanitary	- closures - Fittings	- adhesion - homogeneous layer - abrasion	PVD Cr(III)		- Costs - Capacity - Layer quality	- substrate variety - product variety	no
Group 6: Repair / spare parts									
		Oldtimer/ spare parts							no
		- Reprocessing - recycling							no

Table 4: Conditions of substitution decorative functional – part 2

2.8 Special case: Pre-treatment of plastics

a. Generally available as an alternative to the use of Cr(VI) for decorative coating (see above) – extended analysis

A current compilation can be found at: **/16/.**

1. Mn(III)-based process

The manganese (III) – manganese (II) system is fundamentally suitable for the process due to its high oxidation potential (1.5V) and its high stability in sulphuric acid. No decomposition, changes to the oxidation state or precipitation occur. Moreover, no material changes need to be made to the treatment process unlike when using chromo-sulphuric acid, and both ABS and PC/ABS can be processed.

The process is suitable for coating using a chemical nickel and copper plating process. No experience with chromium plating can be reported as things stand today.

TLR 6 - system/sub-system modular prototype demonstration in an operational environment.

2. Potassium permanganate with phosphoric acid

The process for coating ABS and PC/ABS that is currently being most extensively tested involves the use of potassium permanganate in conjunction with a variety of electrolytes. On four different types of plastic, very even roughening can be observed with minimal penetration depth. Notwithstanding this, the process is very complex in terms of process management. Two issues that have not yet been conclusively resolved concern long-term stability and the precipitation of manganese dioxide (MnO_2)

TLR 6 - system/sub-system modular prototype demonstration in an operational environment.

3. Permanganate with organic pickling solutions

A system is being tested involving permanganate in conjunction with organic pickling solutions.

This enables the wetting of the plastic substrate to be improved by allowing an organic component to penetrate the plastic. Amending the plastic surface enables the necessary caverns to be formed.

The process is being tested for ABS as well as PC/ABS.

Field tests are taking place; the results have yet to be revealed.

TRL 5 - Component and/or breadboard validation in relevant environment

4. Change in the surface structure – Biconex process /17/

More recent processes /18/ are based on changing the surface structure using organic agents.

“Softening” the surface allows the caverns required for activation to form.

As yet, the findings available on long-term usability are still inadequate.

TRL 5 - Component and/or breadboard validation in relevant environment

16 Beizen von Kunststoff - https://www.wotech-technical-media.de/womag/ausgabe/2015/12/26_zvo_berlin_12j2015_3/26_zvo_berlin_12j2015_3.php
17 https://www.wotech-technical-media.de/womag/ausgabe/2018/11/26_hofinger_kunststoff_11j2018/26_hofinger_kunststoff_11j2018.php
18 Description of Bionex - https://www.biconex.de/

5. Sulphonation and use of peroxides

The possibility of using sulphonic acid and peroxide-based agents is also being examined.

Both substances can only be managed with great time and effort, however, and cannot be used in the long term given their low chemical stability.

TRL 5 - Component and/or breadboard validation in relevant environment

b. Pending technical issues

As before, the analysis carried out in the submitted application describes the current development status

- The aforementioned processes are currently on a technical readiness level (TRL) between 5 and 6. As of today, none of the processes can be implemented in practice with any degree of promise.
- No releases have yet been granted by any customers.
- Developments in polymer technology suggest that further intensive development is to be expected.
- Approvals or licences from government authorities and end users are essential.
- Work is underway to reach a stage of implementation, though any production-related impementation will first require having a safe form of technology.
- Significant factors include the insufficient, long-term adhesion of the downstream coating and the, as yet, insufficient process reliability.

2.9 Key application – Black Chromium

2.9.1 Description

Like decorative chrome, black chrome is usually deposited in combination with a nickel layer (bright nickel or matt nickel). It is a very special finishing which is used for very special and high-quality applications.

What is required is adjustable electromagnetic properties as well as dense layers with sufficient structuring for colouring and achieving adequate electromagnetic properties. At the same time, black chrome is used for the production of matt black surfaces. Due to the excellent bonding properties, it is often used as a sub-layer for an additional coating system.

Black chrome offers a hard surface with corrosion and wear resistant properties. The appearance of black chrome depends on the type of substrate and the surface treatment prior to galvanisation. The surface can be glossy, semi-glossy or matt. The surface can be waxed or oiled to improve the final appearance.

The requirements for the coatings in the various applications/utilisations are very different. Above all, in optical and electronic applications the functions required are critical for substitution.

1. Coating requirements

Function:	Evaluation / Necessity:
Certification	Chrome-plated parts must be tested and qualified for the intended use
Corrosion	Durability
Layer homogeneity	Functional requirement end product
Porous-free	Porosity would have a negative impact on the function and appearance in the long term
Visual appearance/design	Quality aspect - increases the long-term value
Gloss / Brilliance	Quality aspect - increases the long-term value
Haptics / Valent appearance	Improves the added value of the end product
Flexible roughness tolerance	Precision engineering and process requirements
No unexpected layer deposits	Precision engineering requirements
Adhesion	End product requirement
Prevention of tarnishing colors	End product requirement
Optical reflection	Functional requirement
Thermal conductivity	Functional requirement
Electrical conductivity	Functional requirement
Thermal stabilit	Functional requirement
No thermal load substrates	Precision engineering / optics

2. Available technical alternatives

The following technologies are specified as being “fundamentally available” and thus implementable alternatives for black chromium:

- Cr(III) process
- PVD
- Painting

The processes are technically available as in the decorative-functional application. In case of PVD and painting they can be described by a TRL level of 7 and higher, i.e. generally available. In case of Cr(III) technology, the deposition of matt black chrome layers is not yet possible. Here a TRL level of 4 to 5 should be assumed, i.e. the technology is still in development.

Risks can be named in all cases. But the CMR risk can be reduced by using the alternative technologies so that the general availability is confirmed.

3. Areas of Applications / utilisations

Comparable substrates and technologies are used in all of the application areas described below. However, areas such as medical technology, electronics and optics are subject to special requirements.

General requirements:

- Automotive
- Mechanical Engineering
- Motorbike parts – Classic Cars
- Corrosion protection at high temperatures

Special requirements:

- Electrical industry / electronic components:
- Consumer electronics
- Optical industry / photo industry
- Medical Technology
- Laser Technology
- Measurement industry

2.9.2 **Extended Analysis and updated AoA**

- Cr(III) Technology
  Contrary to the decorative application, it is currently not possible to deposit suitable black chrome layers by means of Cr(III).

- PVD
  PVD can be used under special conditions. Currently only small quantities are produced. The problem is often the complexity and the delicate and intricate shape of the parts. Furthermore, adhesion and uniformity are not achieved on optical components. Hollow parts cannot be coated on the inside at present. This is a problem for optical hollow conductors.
  Special PVD processes are used in the high-temperature range. They achieve layers with a temperature resistance of up to 900 °C. A standard application is not possible.
  In the field of optics and laser technology the necessary reflection resistance is not achieved.

- Painting
  Delicate and intricate parts cannot be reliably coated with painting technology. The necessary uniform requirements of electronic and optical components cannot be guaranteed. The coatings are not stable in the high-temperature range.

2.9.3 Implementation or development of available alternatives

In many areas, studies are already being conducted into the application of the technologies described. The cooperation with customers is very different. Due to the very different parts and requirements, many investigations are carried out by the customers themselves without the involvement of the job-platers.

The requirements are the strictest in the field of optics and electronics, especially with regard to optical reflection properties and electrical conductivity. These are strongly determined by the design and are therefore in the hands of the customer or user.

Table 5 summarises the experiences of the VECCO companies.

1. Assessment or activities of the companies

- Cr(III) is currently not being developed in the black chrome sector
- In special cases, PVD and painting are an alternative that is already in use
- Significant development is necessary for different part geometries
- There is interest in joint R&D initiatives

but:

- Substitution plans are prepared by customers without involvement of the coaters
- In the case of uses that are too special, such as in the optical and electronic sector, individual authorisations should be reconsidered
- Many plants will probably close down when Cr(VI) is no longer possible. This assessment is independent of the possible alternatives and is based on the individual development possibilities of the companies (see also analysis sec. 2.3)
- The involvement of the jobplaters by the customers is a key for successful substitution.

2. Pending technical issues – R&D needs

In principle, the applicability of Cr(III) technology has to be developed. However, this is still a laboratory task. PVD technology, on the other hand, can already be applied, but it needs to be adapted.

- Properties of the chrome layer:
  In the area of homogeneity and reflectivity there is an intensive need for R&D of other technologies such as PVD and painting. For the electroplating companies, however, there is only limited possibility for cooperation here.

- Stability of the layer - adhesion and valence
  The possibilities for increasing the quality of the final layers must be improved. Thermal stability must be improved as well.

- Hollow parts:
  Optical hollow conductors cannot be reliably coated with any other technology but black chrome at present.

- Approval / Certification:
  As the products are often used for a very long time and the characterisation is done by corresponding standards or requirement profiles, the new technologies have to be checked for compliance.

3. Pending aspects related to production engineering- R&D needs

The industrial implementation requires higher demands on production.

- Coating throughput
  PVD as a suitable coating is currently not yet applied with sufficient throughput to achieve the required quality

- Coating capacity
  At the same time, the necessary throughput cannot yet be guaranteed.

2.9.4 Implementation or developments

Investigations are already being carried out in many areas on the application of PVD and painting. However, there is only limited cooperation between the coaters and their customers.

Technological development in the application areas:

- Optics and electronics
  Further R&D by customers
- Writing utensils
  No result yet due to the various requirements for design and functionality. It is estimated that the products will become more expensive by a factor of 3 - 5.
- Thermal applications
  Coaters regularly test the applicability of e.g. black nickel. Customers request more and more suggestions from the coaters
- Medical technology/Aerospace/Security technology
  There is a continuous search for safe coatings. It is currently not possible to replace black chrome by Cr(VI) electrolytes.

2.9.5 Possible groupings

The discussion allows the following summary of uses:

1. Optics and reflection
2. High temperature applications - temperature stability
3. Intermediate layers: qualification of the final layer

The following compilation of the discussions above makes no claim to completeness due to the wide variety of utilisations.

However, it will be updated in the context of further developments for substitution and serves as a basis for the IT-supported database.

Substitution possibilities black chrome

	Description			Evaluation				Substitution
	Utilisation	Details	Requirements	Alternative	Experiences company and customer	Barriers	Challenges for developments	Substitution possible?
Group 1: Reflectivity and electronics	Electrical industry electronic components	e.g. concert equipment	- electrical conductivity of components - Insulation	paint		defined electrical properties		conditionally
	Consumer Electronics		- electrical conductivity of components - Insulation	paint		defined electrical properties		conditionally
	Photo industry	- movable small parts for cameras - Parts slenderly built - Temperature Sensitive	- no reflection - partial formability	- paint - Black Nickel	customers: - paint tested negative - Black nickel negative For apertures: - Abrasion - Coating thickness (lacquer)		- filigree - reflection protection	no
	Optical industry	- Measurement industry - Parts slenderly built - Temperature Sensitive	- layer homogeneity - no reflection	- paint - PVD	PVD - poor adhesion ("stem growth") - higher temperature - Coating time.		- layer homogeneity - reflection protection	no
	Optical industry	- Light beam guidance Measuring devices	- no reflection - Interior coating	- paint - PVD	- Internal coating not possible	- Hollow conductor - interior coating	- interior coating Innenbeschichtung	no
	Optical industry	- undisturbed fiber optic cable in measuring devices	- no reflection	- paint - PVD			- layer homogeneity - reflection protection	no
Group 2: Thermal stability	Medical technology	surgical instruments	- abrasion resistance - anti-reflection	PVD	- used because of its high hardness and abrasion resistance under normal conditions; - joints problematic		- abrasion resistance - no reflection	conditionally
	- laser technology - heat sink	Laser Technology: Beam guidance	Temperature resistance due to absorption				Thermal load of the beam guiding components	no
	Automotive	Exhaust pipes, covers, engine components etc.	- corrosion protection - tarnish protection	PVD		costs and geometry	Geometry of the parts	conditionally
	Motorbike	Exhaust pipes, covers, engine components etc.	- corrosion protection - tarnish protection	PVD	used by requirement	costs		yes
	Mechanical Engineering	eg. Tools	- corrosion protection - tarnish protection					
Group 3: Quality final layer	Writing instruments, high price	Interlayer for quality Final layer	- liability - uniform layer	PVD	PVD - poor adhesion ("stem growth") - higher temperature - Coating time.	Costs capacity layer quality		conditionally
	Black chrome on stainless steel	Finishing surface	- liability - abrasion	PVD	- Good adhesion - colour comparable to black chrome	costs		yes

Table 5: Conditions of substitution Black Chrome

2.10 Functional – Hard chrome

2.10.1 Description

Functional coating with chromium trioxide is usually known as hard chrome. Hard chrome is characterised by much thicker layers and is used in applications that have extremely demanding requirements for wear and durability. The parts in question are generally used in precision engineering, in the manufacture of durable goods, in goods that are subject to aggressive or very demanding environments and to strict quality and certification requirements. The ability of the coating to be reworked is an important feature. The components can be decoated, chromium-plated and ground to size without destruction. These properties are particularly important for repairs, where hard chrome is often used. This aspect of resource efficiency is a major argument in favour of this technology.

The actual applications in the industry are very diverse and usually require a maximum of robustness. But that would be too simple to put into words. Looking at the specific applications, a whole list of key functionalities emerges

1. **Coating requirements**

Function	Evaluation / Necessity
Certification	Chromium-plated parts must be inspected and qualified for their intended purpose.
Corrosion	Durability
Friction and wear protection	Durability
Hardness, Abrasion, Layer thickness	Durability
Biocompatibility	Lack of reactivity with biological environments
Surface morphology	Structuring and stability
Accumulated functions	Linkage / combination with other end-product parts
Possibility of repair	Process characteristic
Resource efficiency	Process characteristic
Tribological properties	Wettability, tarnish protection, roughness, temperature

Function	Evaluation / Necessity
Certification	Chromium-plated parts must be inspected and qualified for their intended purpose.
Corrosion protection	Durability
Corrosion protection	Durability and function in aggressive environments
Chemical stability	Use in aggressive or sensitive environments
Thermal stability	Use in changing conditions of heat/cold
Friction and wear protection	Durability
Wear protection	Durability
Low friction	Technical requirement
Hardness / Abrasion / Layer thickness	Durability and stability

Abrasion resistance	Durability
Hardness	Durability
Controllable thickness	Requirement precision engineering
Porous-free	Durability and stability
Good ductility	Important for tool production
Biocompatibility	Lack of reactivity with biological environments
No release of nickel	No skin sensitizer (like nickel)
Biocompatibility	Lack of reactivity with biological environments
Medicinal use	Lack of reactivity with biological environments
Food Resistance	Lack of reactivity with biological environments
Skin compatibility	Must not be a skin sensitizer
Surface morphology	Structuring and stability
Adhesion	Stability of the coating
Anti-adhesive	Tribological property
Microcrack Network	Corrosion and adhesion
Self-supporting	Stability in complex systems
Minimum tolerances	Precision engineering
Maximum glide	Precision engineering
Elasticity	Use in robust environments
Polishing ability	Requirement in rework processes
Layer homogeneity	Functional requirements in the finished article
Accumulated functions	Connection / combination with other parts of the end product
Haptics/value perception	Improves the added value of the end product
Magnetic barrier	Requirement in most equipment containing electronics or electrical circuits
Thermal conductivity	Must quickly release thermal currents or affect the final use

In contrast to decorative-functional plating, here possible alternatives are very much geared towards special applications (utilisations). Thus there are some, very specialised, alternative processes.

2. Technical alternatives available

In the case of functional chromium plating, the following technologies are deemed "generally available" and thus feasible alternatives:

Potential alternatives for functional chromium plating based on chromium trioxide (BAuA Study 2020 /7/)

1. Laser Cladding
2. Salt bath nitriding
3. Salt bath nitrocarburising
4. Plasma nitriding
5. Thermal spraying
6. Thermal spraying with inductive heating
7. Physical vapour deposition
8. Trivalent chrome plating processes
9. Applications with no identified alternatives

According to the "analysis of the alternatives" discussed in the applications for authorisation, it must first be examined whether the risk is actually reduced by the alternative technology and whether it is technically and economically feasible for the applicant. This depends largely on the respective areas of application. For hard chrome, we have formed the following subgroups (utilisations).

3. Areas of utilisation

For the wide scope of the hapoc Afa we have defined 15 different subgroups. Of these, 12 subgroups are to be assigned to the area "Functional / hard chrome“. On the basis of these "utilisations", the necessity of drawin-up a substitution plan according to the SAGA concept will be assessed.

1. Food industry (functional)
2. Defence technology (functional)
3. Power engineering (functional)
4. Automotive - machines/drive (functional)
5. Automotive - interior/exterior (decorative)
6. Textile industry (functional)
7. Aviation / Aerospace (functional)
8. Consumer (functional)
9. Mechanical engineering / Plant construction (functional)
10. Plastics and Packaging industry (functional)
11. Sanitary (decorative)
12. Furniture (decorative)
13. Repairs (functional)
14. Medical technology (functional)
15. Toolmaking (functional)

2.10.2 **Extended Analysis and updated AoA**

1. Available as an alternative to the use of Cr(VI) for functional applications

In order to develop this substitution plan, Vecco e.V. has carried out a series of webinars with its members in order to gather experience with substitution technologies, the most important technologies are:

- Cr(III) process
- PVD
- Thermal Spraying
- Nitriding

Other technologies mentioned by the companies in the webinars are:

- Laser cladding (Highspeed)
- Nickel-based technologies

a. Cr(III) Technology:

- Chromium-III based processes for hard chromium are being developed
- Compared to decorative at a very early stage of development
- Corrosion requirements are only met by additional under-nickeling
- Hardness requirements are only met by additional heat treatment
- Layer deposition is much lower. No thick layers (e.g. 200 µm) can be deposited
- Tribological properties such as the anti-adhesion effect are not achieved
- Nickel release is a problem in sensitive industries (Medical technology, Food industry)
- Companies complain about the insufficient input of chemical suppliers in R&D

Economic aspects and costs

- Deposition rate is about factor 0.5 (higher process costs)
- Reduced life cycles of electrolytes. Higher costs for bath management and maintenance
- Waste water plant: Much more expensive due to complexing agents
- Invest: Integration into existing plants may be possible
- Invest: Chrome (Cr-VI) baths and arrangements must be disposed of
- Invest: Cost € 175,000 to 300.000 per line (not including nickel and heat treatment)

Risk assessment

- Under risk considerations, Cr(III) is preferable to chromium trioxide.
- Coating systems contain nickel and boric acid. In each case on the candidate list of REACh

TLR 6 - System/sub-system model or prototype demonstration in an operational environment.

b. Physical Vapour Deposition (PVD)

- Deposition of very thin layers of 2-5 µm.
- Corrosion protection is hardly given.
- Corrosion protection is achieved in combination with additional galvanic coating
- High hardness and good protection against abrasion
- Areas of application in functional sector (e.g. sewing needles)
- Chamber kiln size is a limiting factor

Economical aspects and costs

- For batch operation, production output is dependent on the chamber kiln size
- Experience shows that production costs are higher than for hard chrome
- High investment costs, since several systems are often needed
- Very energy-intensive process
- High qualification costs for employees (recruitment, training etc.)
- Project costs for PVD implementation between € 1.0 million and € 5.0 million

Risk assessment

- Under risk considerations, PVD is preferable to chromium trioxide.
- Galvanic production of Cr(VI) targets for PVD could shift the problem

TLR 9 – Actual system. Flight proven through successful mission operations

c. Thermal spraying:

- Thermal spraying coatings cannot produce pore-free layers
- Pore-free layers are a necessary requirement for corrosion protection (infiltration/chipping)
- Chrome layer is the shaping element in the production of plastics (Plastic industry)
- Chrome layer has direct contact with the plastic melt (Plastic industry)
- Thermal sprayed cylinders are not resistant to some plastics (Plastic industry)
- Exact concentricity and cylindricity of < 5 µm cannot be achieved with thermal spraying
- Less adhesion than hard chrome

Economic aspects and costs

- Due to the use of expensive additives/powders thermal spraying is more expensive
- Due to the porosity, thicker layers must be applied for grinding
- Mechanical reworking is more expensive due to the higher hardness and frangibility
- Longer grinding time and use of diamond-set grinding wheels
- Higher energy consumption as with hard chrome

Risk assessment

- Thermal spraying generates respirable A and E fractions.

TLR 9 – Actual system. Flight proven through successful mission operation

d. Salt bath nitriding:

- Corrosion-resistant and hard surfaces with a black appearance
- Process is used worldwide and can be considered as TRL 9
- Asian and American suppliers are relying on this process for e.g. engine valves
- Abrasion, hardness and corrosion show comparable values to hard chrome
- Not all substrates can be treated
- Black surfaces are difficult to test with automated optical robot-systems

Economical aspects and costs

- Salt bath nitriding is less costly to use
- There are few suppliers in Europe, making investment in the technology comparatively more expensive
- Capacities are being built
- Technology requires separate periphery (exhaust air and waste water technology)
- Investment costs for the introduction are € 2-4 million

Risk assessment

- Salt baths contain cyanides
- High OSH requirements / Highly toxic
- Risk assessment was already discussed in the trialogue.

TLR 9 – Actual system. Flight proven through successful mission operations

e. Laser Welding (High Speed)

These processes are currently being tested (e.g. EHLA). The technology is used in applications where small areas have to be coated selectively. Repair or reworking is an issue here.

f. Nickel-based processes

In connection with nickel, it has been pointed out several times that nickel has been on the REACH candidate list for some time. The replacement of an SVHC substance by an SVHC substance does not seem very promising due to the expensive additional investments. In the field of slide bearings it was pointed out that nickel is not "roll-over-capable". Combinations with an additional heat treatment or Cr (III) layer (Savroc) were evaluated as insufficient in tests. Investments and energy consumption were also assessed as negative.

There are available alternatives in some utilisations of functional chromium plating. Whether these are technically and commercially feasible for the applicant depends strongly on the companies possibilities (see sec. 3).

However, all these technologies working in niche applications have in common that they reach their limits outside of these specific applications.

A generally available process that can be used for all the applications in functional chroming is not in the pipeline. Galvanic processes are still the most likely to be implemented here. Cr (III) technology is still far behind in comparison to the decorative applications.

First approaches by Atotech, Conventya (Durathree) have to be tested. To replace hard chrome, a company would have to develop about two to three additional alternatives. Taking the example of the cost of setting up the alternative salt bath nitriding, with investment costs of around € 2 - 5 million, it is clear that this is not a commercially viable option for the job-plater SMEs.

In this respect, we note that from an economic point of view some existing alternative technologies are not economically feasible for the applicants and therefore cannot be described as generally available, in the definition of the SAGA-concept (see sec. 3).

2. Pending technical issues:

a. Cr(III) Technology

Although Cr(III) technology is the most promising galvanic alternative, several developments are still necessary:

- **Properties of the chromium layer:**
  Tribological properties such as abrasion or adhesion as well as corrosion protection properties are not yet sufficient. The composition and structure of the chrome layer is not yet clearly reproducible. Fe-Ions or other substances are incorporated and influence the properties.

- **Substrates to be coated:**
  This is a major problem. While plastic substrates can be coated successfully in the foreseeable future, metallic substrates are still difficult. Iron-based components contaminate the electrolytes with Fe ions, which can be incorporated into the layers and have a significant impact on the deposition kinetics. Non-ferrous metal based substrates cannot yet be coated with an adhesive coating. No systematic findings are yet available for die-cast parts.

- **Hollow parts:**
  Currently, Cr(III) technology is not suitable for coating metallic hollow parts due to the reaction kinetics.

- **Approval:**
  As the products have often been used for a very long time and the characterisation is based on corresponding standards or requirement profiles, the new technologies must be checked for compliance.

- **Operating costs:**
  The costs of electrolyte management are significantly higher. Similarly, the costs of waste water treatment are many times higher. Here the manufacturers have been asked to offer more marketable products.

- **Requirements for maintenance (electrolytes) (see also decorative)**
  Due to the risk of contamination with Fe ions, maintenance such as analysis and cleaning of the electrolyte is much more demanding.

- **Development of additives, e.g. complex stabilisers (see also decorative)**
  Adapted chemicals are necessary for stable production. At the same time, these must not pollute the environment and must be degradable in wastewater treatment plants.

- **Coating capacity - Cr(III) is slower (see also decorative)**
  As the coating process is currently not yet as fast, an adjustment must be made to the production capacity. This is accompanied by the development of suitable electrolytes.

- **Waste water treatment / environmental aspects (see also decorative)**
  The Cr(III) technology requires complex waste water treatment as the electrolytes require many additives such as complexing agents. The stability of the additives required can lead to complex degradation products, which are critical for the environment and additionally burden the wastewater treatment plants.

b. PVD Technology

- **Scope of parts**
  It has been stated that PVD technology only works for smaller parts. For larger parts, the chamber size is a limiting factor. However, a 20 m roller will probably hardly ever be able to be coated with such a technology.

- **Reworking**
  The introduction of PVD costs approx. € 5 million per site. Here it must be taken into account that ideally, a separate chamber must be available for each colour.

c. Salt bath nitriding technology

- **Capacity**
  Salt bath nitriding is globally a mature process which is used millions of times. There are also corresponding plants in the EU. However, as the focus of European manufacturers is still on chrome plating, capacity has to be generated.

- **Visual testing**
  Millions of pieces have to be visually tested automatically. In our opinion this is not yet possible.

- **Price**
  All over the world, salt bath nitriding is cheaper than chrome plating. In Europe it is the other way round. This could be due to fewer suppliers and little competition. More competition could create medium-term advantages here.

2.10.3 Implementation or developments

Investigations are already underway in many areas to apply Cr(III) technology and other processes. However, there is only limited co-operation between the coaters and their customers.

Technology development in the application areas

Automotive
- Automotive functional / Exterior - Cr(III) partially available
- Automotive functional / Drive engineering / valves - salt bath nitriding partially available
- Automotive functional / Slide bearing - PVD partially available

Consumer
- Consumer / Sewing needles - PVD and Cr(III) partially available
- Consumer / Rollers - currently no alternative

Mechanical Engineering
- Hydraulics - currently not available
- Plastics industry - currently no alternative
- Printing industry - thermal spraying / electroless nickel partially available
- Functional parts -Cr(III) partly available
- Gravure printing - currently no alternative

Medical Technology
- Currently no alternative

Repairs/Spare parts
- Currently no alternative

Defense Technology
- Nitriding partially available

Tools
- PVD partially available
- Trend towards chrome

2.10.4 **Assessment and activities of the companies**

Vecco companies are looking into alternative technologies:

- In the field of mechanical engineering/roller chrome plating, tests with Cr(III) have also been carried out by Vecco member companies. The deposit was definitely made. However, the high layer thicknesses (200 µm) could not be achieved at all. Accordingly, wear and abrasion were not sufficient. The lifetime of the CrVI rollers was shown as factor 4-5. With regard to resource efficiency, this is a value that is not accepted by the end customer.

- In the industrial chrome plating of sewing needles, only a thickness of 1.5µm is applied. Here, initial tests with Cr(III) were evaluated promising. It was possible to deposit layers with a hardness of 1000 HV. Field tests are currently underway to evaluate the technology.

- The same member reported positive experiences with PVD (titanium nitrite) in the coating of sewing needles. About 15% of the parts can and are now coated in this way. Unfortunately it cannot be transferred to the whole spectrum of 13,000 parts.

- A manufacturer of plain bearings in the automotive drive segment also commented positively on PVD. In this application, corrosion protection is a secondary feature. What was interesting here the statement that PVD is even cheaper than hard chrome in this case. The transfer to the entire spectrum of parts is not successful because the chamber size is a limiting factor.

- In the field of hydraulic cylinders, one member carried out tests with Cr(III). The samples produced came from India and were nickel-plated. Hardness and abrasion were not comparable with hard chrome. However, standard applications could possibly be covered by them. The order of magnitude of these standard applications is about 30 %.

- In the manufacture of rollers (high brilliant mirror-finish) for the production of plastics, one member reported several problems with thermal spraying. Even the smallest inhomogeneities are reflected on the surface with every roll revolution (technical term: unwinding). For high precision of the plastic products produced (i.e. material thicknesses, especially for optical applications such as touch screens, TFT monitors etc.), exact concentricity and cylinder shape are absolutely essential. For this purpose, the layer applied to the component surface must be mechanically processed to a mirror finish of reproducible roughness values Rmax < 0.025 µm (= 25 nanometres). This is only possible with hard chrome.

Conclusion

In some application areas there are already alternative technologies available (Utilisation). However, all these technologies have in common that they cannot be used in other application areas because other key functionalities are needed. There is no 1-1 technology in sight that would enable the changeover in all the application areas of functional chroming. Although the need to draw up a substitution plan is understood, many job-platers see themselves as the wrong contact. The end customer or the person responsible for the component must be made responsible. Here it is necessary to create a platform where the practical R&D work can take place. In this context we refer to the innovation network in section 3.1.

Due to the limited possibilities of the companies, the implementation of some known alternatives such as salt bath nitriding or PVD is not economically feasible for the applicants and should therefore not be considered “generally available”. The implementation of timelines is therefore only presented as an example in section 3.

The most promising technology for electro-plating companies is Cr (III) Technology. However, this technology is not yet ready for series production in functional coating. The time required here will be longer, as in the decorative sector. When asked, the companies quoted a figure of at least 5-6 years. The substitution plan developed in section 3 can therefore also be called R&D plan.

The following compilation makes no claim to completeness due to the wide variety of utilisations.

However, it will be updated in the context of further developments for substitution and serves as a basis for the IT-supported database.

Substitution possibilities functional / hard chrome									
	Description				Evaluation				Substitution
	Group	Application	Details	Requirements	Alternative	Experiences company and customer	Barriers	Challenges for developments	Substitution possible?
Group 1	Automotive functional	Automotive Exterieur	Bumber, Mouldings, PDC	- Optics - Corrosion - abrasion	Cr(III), PVD, ePD	partially available	Substrates		conditionally
	Automotive functional	Automotive Machines / Drive	Valves	- Hardness, Wear protection - Abrasion	Nitriding	partially available	Customer concern, Not all substrates , Testing		conditionally
	Automotive functional	Automotive Machines / Drive	Axes, Rollers, Gear Unit, Bearings	- Hardness, Wear protection - Abrasion	Hardening, PVD	partially available	Size of the chamber	Chamber size, Investment Alternatives	conditionally
Group 2	Consumer	Mechanical Engineering	Sewing needles	- Tribological Properties - Sliding proporties	Cr(III),PVD	partially available	Tribological p., Substrates	Tribological properties, not all Substrates	conditionally
	Consumer	Packaging	Rollers	- Tribological Properties - Wear, Corrosion	Thermal spraying	currently not available	Thickness, Wear	Optimized coating deposit	no
	Consumer								
Group 3	Power Engineering	Technical parts		Currently no Information available by Vecco members		currently not available			not known
	Power Engineering								
	Power Engineering								
Group 4	Plastic and Packaging industrie	Packaging	Rollers	- Tribological Properties - Waer, Corrosion	Thermal spraying	currently not available	Thickness, Wear	Optimized coating deposit	no
	Plastic and Packaging industrie								
	Plastic and Packaging industrie								
Gruppe 5	Food industry	Technical parts		- Biocompatibility - Certification	Cr(III), PVD, Thermal Sprying	currently not available			no
	Food industry								
	Foodindustry								
Gruppe 6	Aviation / Aerospace	Technical parts	Landing gear components, axes etc.	Certification, Wear, Corrosion, Tribological properties, gas tightness - Corrosion - abrasion	Cr (III), HVOF, Chem. Nickel	currently not available	Security reasons		no
	Aviation / Aerospace								
	Aviation / Aerospace								

Table 6: Conditions of substitution functional Chrome – part 1

Substitution possibilities functional / hard chrome

	Description				Evaluation				Substitution
	Group	Application	Details	Requirements	Alternative	Experiences company and customer	Barriers	Challenges for developments	Substitution possible?
Group 7	Mechanical engineering	Hydraulics	Piston rods	- Hardness - Wear, Tribological properties	Cr(III) under-nickeled	Testing	Costs Corrosion	Maintenance Thickness Costs	no
	Mechanical engineering	Rollers/ rollers	Paper, foils, plastics	- Hardness - Wear, Tribological properties	Thermal Spraying	negativ	mirror high gloss not possible		no
	Mechanical engineering	Printing industry	plate cylinder, reversing drum, side plates	- Hardness - Wear, Tribological properties	Thermal Spraying	partially available			conditionally
	Mechanical engineering	Functional parts	Various	- Hardness - Wear, Tribological properties	Thermal Spraying				not known
	Mechanical engineering	Textile Industry	Yarn Rollers	- Hardness - Wear, Roughness	Thermisch Spritzen				no
	Mechanical engineering	Gravure printing	Print roller in cylinders	Roughnesst, Micro-cracking, Wettability	Cr(III) Plasma special plastics	Testing			conditionally
Group 8	Medical Technology	Medical facilities	Medical facilities	Biocombatibility, Cleanability, certification		currently not available	Security		no
	Medical Technology	Instruments	Instrumente, Pistons, Facilities	Biocombatibility, Cleanability, certification		currently not available	Security		no
Group 9	Repair	Individual products	Rollers, cylinders, piston-rods, Hydraulics	Repairability, To be grinded, High layer thickness	Laser cladding	currently not available	Costs		no
	Repair								
	Repair								
Group 10	Defence Technology	Various	Gun barrel, armoured conduits	- Hardness - Wear, Tribological properties	Nitriding	partially available	Costs Size of parts		conditionally
	Defence Technology								
	Defence Technology								
Group 11	Tools	Tools	Extrusion-tools, Molding tools	- Hardness, Wear, Temp, Repair, Wettability, tribological properties - Benetzungsfähigkeit	PVD Plasma nitriding				conditionally
	Tools								
	Tools								

Table 7: Conditions of substitution functional Chrome – part 2

2.11 Other applications

2.11.1 Anodizing

1. Requirements

By using chromic acid, the layers are very compact due to the inclusion of Cr atoms.
The following properties are required:

a. Low layer thickness
2-4µm can be achieved, which is necessary for accuracy of fit and narrow tolerances.
Required in medicine and aviation.

b. Good corrosion protection with the low layer thickness
Important especially for castings made of aluminium, where the open porosity of the casting surface causes a chromate structure to be formed in the microstructure.

c. Appearance
The appearance can be varied by suitable process control. Metallic images and plastic surfaces (e.g. PP) are possible, which is an advantage in medical technology.

d. Adhesion of subsequent treatments:
Basis for lacquers and mainly in aviation as a pre-treatment for the bonding of aircraft elements.

e. Al-Alloys:
Use of alloys with a high silicon content and defines roughness

2. Technical alternatives available

Major developments are taking place in the use of sulphuric acid (GS process).

Furthermore, chemical deposition processes (e.g. electroless nickel) are being investigated.

3. Areas of application

a. Aeronautical engineering
Housings, valves, sheet metal, strips and parts for bonding
b. Medical Technology
Valve blocks, housings Valve plates, fittings, NO2 control blocks.
c. Safety engineering
Sensors, sensor housings, control valves and casings.
d. Automotive
Engine components and electronic control elements

4. Extended Analysis and updated AoA

Layers over 6µm are generally not suitable due to the properties of the layers and production throughput.

a. Possible alternatives
Due to RoHS conformity, the order volume for chromic acid eloxal has already decreased. Alternative applications are electroless nickel and sulphuric acid (GS-anodising).

b. Pending technical issues
The use of the process depends on the material. With open-pored materials, a chromate layer is formed in addition to the oxide layer, which makes the parts no longer RoHS-compliant, so that they have already had to be replaced. With denser materials (high Si content of the Al alloys), more compounds are formed with the substrate, so that RoHS conformity is given.

c. At present, it is not yet possible to fully replace Cr(VI) technology in the current fields of application. Especially for the higher Si alloyed materials there is no substitute available yet, especially when tight Rz/Ra tolerances are required.
This requires further intensive R&D efforts.

5. Implementation or developments

For some time now, the companies have been working at full speed on possible alternatives to replace Chromium(VI). Continuous R&D measures are being carried out to this end.

The time required is estimated to be around 2-4 years (until market maturity and testing of current customer applications).

For special applications (medical technology, safety engineering, aviation), the time period depends on the certifications.

2.11.2 Stainless steel colouring

1. Requirements

Using chromic acid, very thin oxide layers of different spectral colouring can be achieved due to the incorporation of Cr atoms in the stainless steel matrix. The following properties are required:

a. Corrosion resistance
b. UV resistance
c. Necessary colour fastness under the smallest layer thickness on stainless steel

2. Technical alternatives available

Various technologies are potentially available:

- Colour deep etching by means of marking etching technology
- Black nickel plating
- Highly alkaline bronzing
- Pad plating with high performance electrolytes
- Plasmatic coatings

3. Areas of application

a. Swimming pools
Colouring of stainless steel for use in chlorinated water.

b. Spectral colourin:
Adjustment of the colour degrees by varying the layer thickness (installation Cr atoms)

4. Extended Analysis and updated AoA

By R&D work, various technologies for "permanent" colouring under UV or chloride exposure were investigated.
Currently there are no alternative coatings or colourings with the required optical, chemical and physical properties available. A continuous examination is carried out by the companies.

a. Potential alternatives:
   The alternatives listed under point 2 were examined.
   All tests, except the proprietary development based on Cr VI, were negative.
   The colouring has dissolved in chlorinated water within a short period of time.
   Since stainless steel is used because of its corrosion resistance, the formation of a continuous passive layer is essential for use in chlorinated water and therefore all the above mentioned processes are unsuitable.

b. Pending technical issues
   - Colouring by the precipitation of heavy metals on the surface, similar to cold blackening. These processes lead to a reduction in corrosion resistance and are therefore not applicable
   - Introduction of metals into the surface by means of electrolysis - here too, the corrosion resistance is reduced
   - Colouring of Nickel with HF - this process removes the corrosion resistance.

5. Implementation or developments

The companies are continuously testing the available technologies. No process is currently available.

Further R&D projects are being carried out.

3. LIST OF ACTIONS AND TIMETABLE WITH MILESTONES

3.1 General approach

3.1.1 Criteria for establishing the time and action plan

The webinars and further interviews conducted with VECCO members have shown that the possibilities of implementing a substitution are largely depend on.

1. **Scenario 1 - Technology-determined:**

   Still insufficient technological availability for specific applications

2. **Scenario 2 - Product determined**

   Safeguarding existing products within the framework of their life cycle.

   The criterion is the use of the final product by the customer within the scope of their own products or product systems. Often the products processed by the coaters are part of a product system that the end customer combines.

   The properties of the products are specifically developed and can only be changed when a new product range is introduced.

   This scenario is relevant for all companies and is controlled by the customers.

3. **Scenario 3 - Small companies - customer driven**

   Possibilities of the companies to convert their own production.

   Typical contract coaters have limited financial and logistical possibilities to change their own product line. The typically small companies with up to 50 employees and a turnover of € 2 - 5 million are highly dependent on customers and the financing possibilities offered by banks.

   Furthermore, the small companies are dependent on a supply guarantee from the customer as they do not manufacture their own products.

4. **Scenario 4 - Large companies - customers and products**

   Larger companies often produce their own product series, the conversion of which they can determine themselves. They often collaborate with large customers with whom they have a long-term relationship.

   Their possibilities for conversion are very broad, both financially and logistically.

The above 4 scenarios are analysed below in terms of a possible timeline.

The aim is to adapt the periods as precisely as possible to the decision criteria.

This should enable the companies to analyse their own possibilities on the basis of these criteria and to implement the substitutions in a targeted and successful manner.

The following analysis assesses the significance of the various parameters in the necessary actions. The essential criteria are:

Decision criterion	Description	Responsibility and procedure
Investment reserve	The companies draw up a financing plan and coordinate it with financial backers. The main aim is to generate financing from their own turnover.	The companies plan on their own responsibility. VECCO supports them.
Depreciation / Amortization	Useful life or tax depreciation to designate the refinancing. Existing production facilities require continuation until final depreciation	The companies plan on their own responsibility. VECCO supports.
Introduction substitution	When can the company plan the changeover?	The companies must be informed about available technologies. VECCO takes on this task.
Technology development	Creation of an R&D plan	VECCO takes over this task
Customer participation	Mandatory for supply security Customer participation must accompany the changeover process	The companies seek contact with customers and agree on changes in production. VECCO supports
Old projects / product cycles	Until the conversion, the company must continue to produce. The current product cycles must be operated.	The duration and type of products are agreed between the companies and the customers.
Spare parts / Repairs	Long-term supply security (spare parts)	

Table 8: Key criteria for successful substitution

Based on this distinction, the following section describes the significance of the criteria in the four different scenarios.

Based on these options, the detailed timeline are then defined on the basis of the criteria developed in sec. 2.

3.1.2 **Assessment economics: finances and investments**

The following figure shows the distribution of VECCO's companies by turnover:

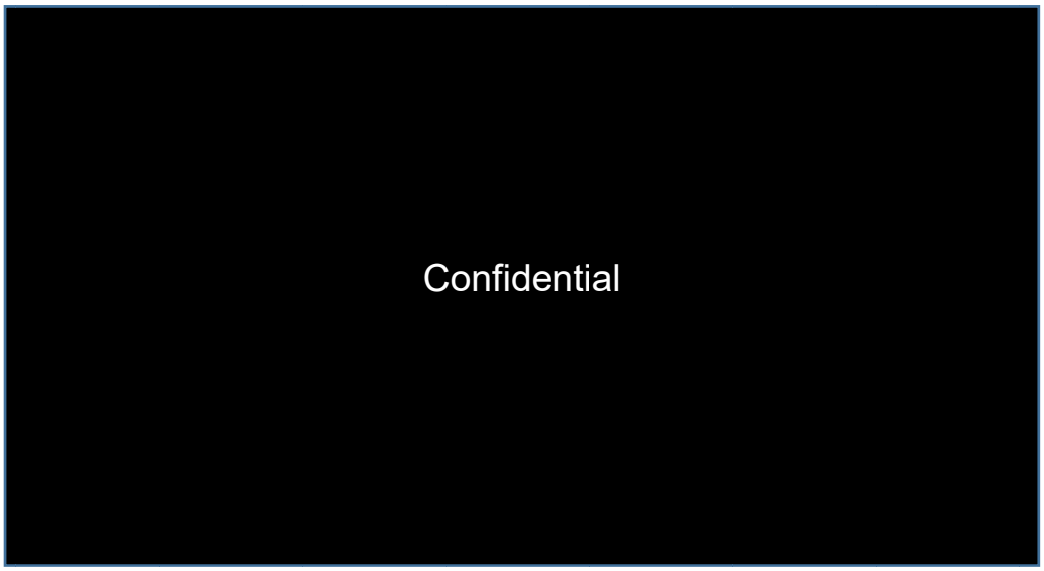


Fig. 3: Distribution of VECCO companies by turnover

On the basis of a return on sales, it is possible to estimate the possibilities that the companies have for financing. Various reserves are compared in relation to the return on sales.

Turnover	Sales return		Investment reserve / years		
			1%	2%	10%
€ 1.500.000	4,5%	€ 67.500	€ 675	€ 1.350	€ 6.750
€ 5.000.000	4,5%	€ 225.000	€ 2.250	€ 4.500	€ 22.500
€ 10.000.000	4,5%	€ 450.000	€ 4.500	€ 9.000	€ 45.000
€ 20.000.000	4,5%	€ 900.000	€ 9.000	€ 18.000	€ 90.000

Table 9: Possible investment reserve VECCO companies

Assuming an investment requirement of 250 T€ for a Cr(III) line the following times for the ROI result:

Turnover	Investment Substitution	Time requirement / years		
		1%	2%	10%
€ 1.500.000	€ 250.000	370,4	185,2	37,0
€ 5.000.000	€ 250.000	111,1	55,6	11,1
€ 10.000.000	€ 250.000	55,6	27,8	5,6
€ 20.000.000	€ 250.000	27,8	13,9	2,8

Table 10: Time requirement / ROI investment

The estimates underpin the fact that scenario 3 for small companies makes the necessary production security absolutely essential.

With this security, however, the companies are able to carry out the substitution.

The following table shows the financial conditions of a substitution for some typical technologies:

	Description	Turnover	ROI at 4.5% sales return
Example 1: Chrom(III)		**€ 5 M**	**2 – 4 years**
Application	Plating on Plastic		
Facility	1		
Costs Invest	€ 250.000 - € 500.000		
Example 2: Chrom (III)		**€ 1 M€**	**5 – 10 years**
Application	Steel materials		
Facility	1		
Costs Invest	€ 250.000 - € 500,000		
Example 3: Salt bath nitriding		**€ 5 M**	**13 – 15 years**
Application	Inlet valve Engine		
Facility	1		
Costs Invest	€ 3 million		
Example 4: PVD		**€ 5 M**	**4 – 15 years**
Application	Furnitues		
Facility	1		
Costs Invest	€ 1 – 5 million		

Table 11: Examples of investment costs of different technologies

3.1.3 **Evaluation of time tables**

The discussion above indicates that achieving a successful substitution depends on various parameters.

The expected course of substitution was described in sec. 1.5. The dependencies named there are substantiated in the following figures, based on the time estimates of the timelines in secs. 3.4.3 to 3.4.6.

Fig. 4 shows the time span to be expected for the decorative-functional application focusing on the substitution by Cr(III) Technology.

The red area describes the situation that the technology is generally available, while the realization depends on the factors described above.

The definition of the time range is based on

1. Customer discussion and acceptance – 2 years
2. Planning and realisation of production line – 1 year
3. Additionally: Product adoption
   This issue describes the subsequent development and will influence the final date of the of the Cr(VI) technology

If substantial R&D is necessary, the time range needs to be extended. The final date will depend on the progress of developments. If the customers will be involved in the projects the realization of the substitution could be decreased to 1 to 2 years.

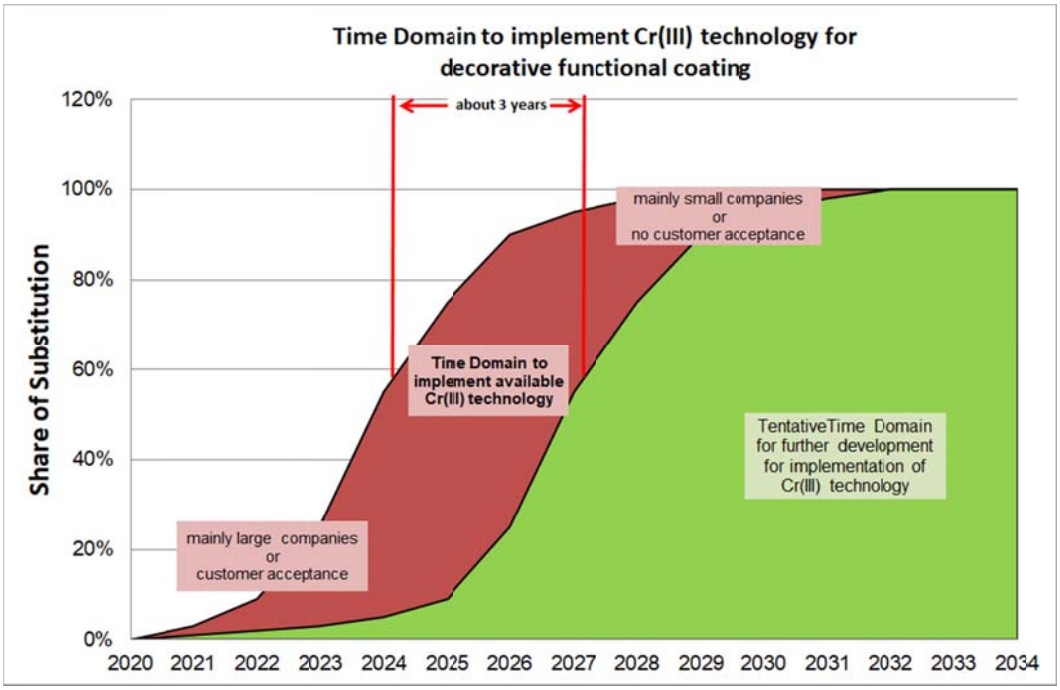


Fig. 4: Time span to realize substitution for decorative-functional, Cr(III) Technology

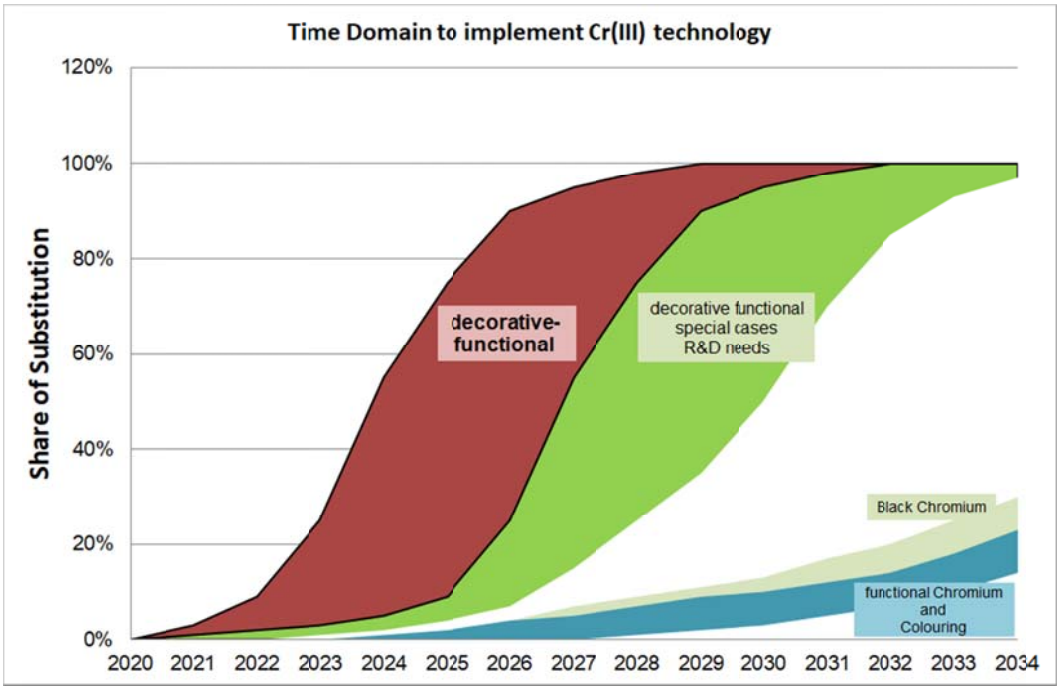


Fig. 5: Time span to realize substitution for all relevant applications, Cr(III) technology

Fig. 5 describes the estimated course of substitution by Cr(III) technology in the applications covered by this proposal.

While the application for the decorative - functional application is expected to be implanted by the end of the 2020s the other applications needs further R&D to be carried out in terms of specific utilisations.

Special applications require highly adapted processes. These must be specially developed. The time required for this cannot be reliably estimated. In individual cases, this may require several years.

Other technologies are already in use, so it is difficult to assess the further development of their use. In all cases, it can be assumed that the growth of the shares will be even, although it will be significantly flatter than in the decorative-functional area

Fig. 6 tries to describe the increase in the case of PVD

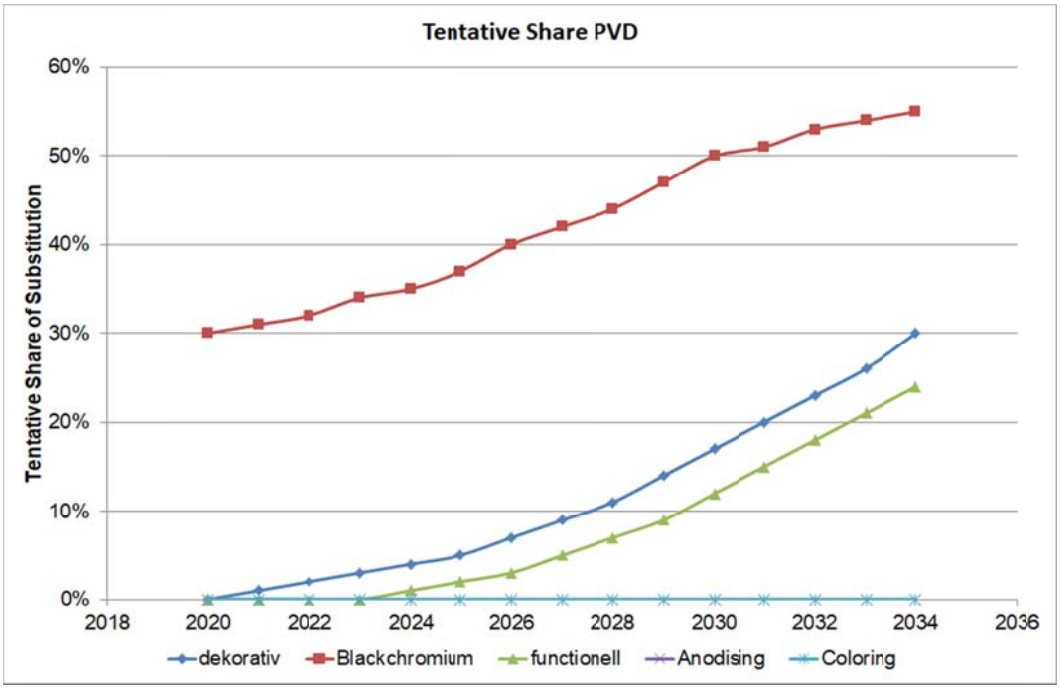


Fig. 6: Tentative time span to realize substitution for all relevant applications, PVD

3.1.4 **Procedure for further evaluation of the scenarios described**

The following analysis is based on a successful technology development. The parameter and criteria developed in sec. 3.1.1 will be used for evaluation.

In the following step, the criteria are evaluated in terms of their significance to implement the substitution. In particular, the specific conditions of the companies are taken into account.

Depending on the progress made with regard to these criteria, a time line will be estimated. The time required for the specific conditions of the companies is continuously adjusted. This is visualized by a suitable graphic.

The scenario assumes that the implementable technology will be available in 5 years. Accompanying the development, the companies can talk to their customers and conduct further negotiations.

This process is substantially supported by VECCO.

3.1.5 **Timetable determined by technology**

Scenario 1	Technology determined
Technology development is decisive	The substitution is determined by the duration of the products treated. Customer participation is not significant over the life of the product, it becomes important when planning new products.

Decision criterion	Description	Varying parameters
Investment reserve	target figure: € 250.000 for Cr(III) Turnover: € 1 - 2 million; investment reserve 2%; duration: 12.5 years	1. use of technology unclear 2. investment costs only estimated
Depreciation / Amortization	Useful life or tax depreciation	1. useful life: necessary repairs and additions
Introduction of substitution - share of sales	When can the company plan the changeover?	1. planning can only take place when the substitution is offered 2. technological security is the biggest problem 3. safe changeover necessary: Specialist companies 4. securing customers and product quality
Technology development	Technology development is of central importance	
Customer participation	Mandatory for supply security Customer participation must accompany the changeover process	1. customer readiness 2. customer know-how 3. field trials
Old projects / product cycles	Until conversion, the company must continue to produce The current product cycles must be served	1. vary the duration of product cycles 2. must also be combined with production facilities of the holding
Spare parts / Repairs	Long-term supply security (spare parts)	

Table 12: Criterion for substitution – technology determined

Decision criterion relevance	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment reserve	10%	10%	10%	10%	10%	10%	5%	5%	5%	5%	5%	3%	1%	0%	0%
Amortization	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	3%	1%	0%	0%
Introduction of substitution - share of sales	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	30%	42%	46%	63%	68%
Technology development	90%	90%	89%	85%	80%	70%	60%	30%	20%	10%	0%	0%	0%	0%	0%
Customer participation	0%	0%	1%	5%	10%	15%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Old projects / product cycles	0%	0%	0%	0%	0%	0%	0%	30%	40%	40%	30%	25%	25%	10%	5%
Spare parts / Repairs	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	5%	2%	2%	2%	2%

Table 13: Decision criterion relevance for substitution – technology determined

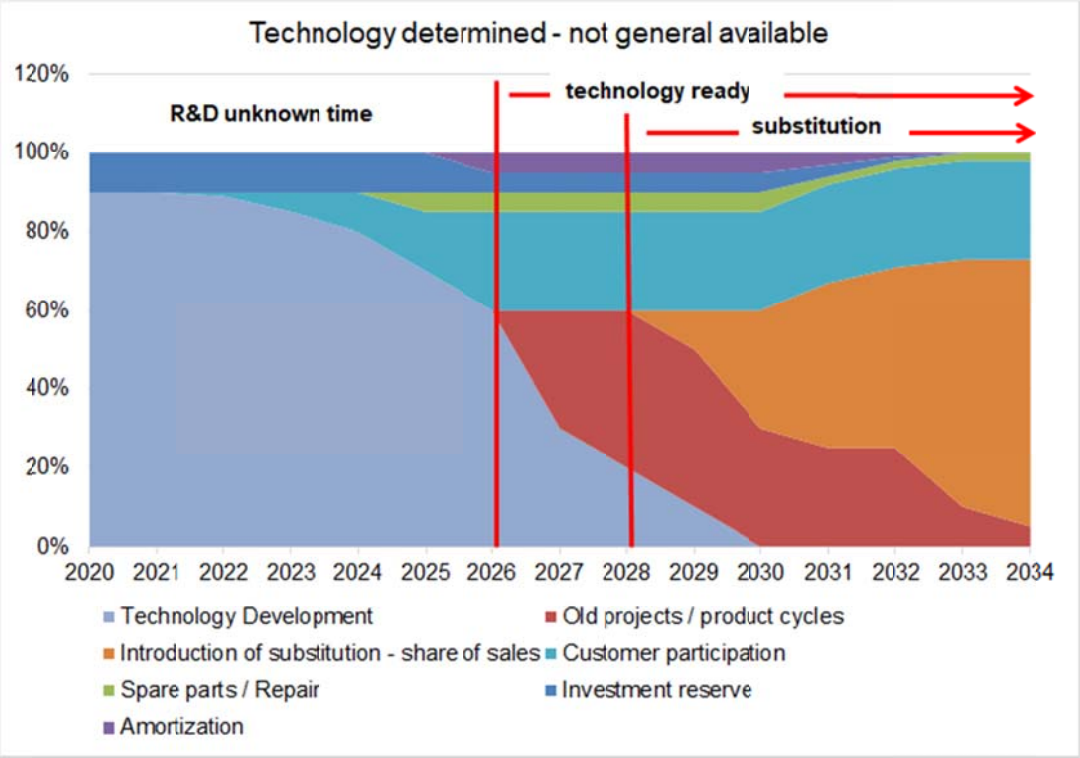


Fig. 7: Time span to realize substitution – technology determined

3.1.6 **Timetable - Product determined**

Scenario 2	**Product-determined: Cycle and lifetime**
Determining product life cycle	Substitution is determined by the duration and lifetime of the products treated. Customer participation is not decisive in the course of the product life. It becomes decisive when planning new products.

Decision criterion	**Description**	**Varying parameters**
Investment reserve	target figure: € 250.000 for Cr(III) Turnover: €1 - 2 million; investment reserve 2%; duration: 12.5 years	1. investment costs 2. variation in turnover
Depreciation / Amortization	Useful life or tax depreciation	1. useful life: necessary repairs and additions 2. date of commissioning
Introduction of substitution - share of sales	When can the product or system product become established on the market?	1. secure conversion: chemical suppliers 2. securing customers
Technology development	Technology must be secure	
Customer participation	Mandatory for supply security: Customer involvement must accompany the changeover process, possibly varying their own product	1. customer readiness 2. the know-how of the customers
Old projects / product cycles	Until conversion, the company must continue to produce The current product cycles must be served	1. vary the duration of product cycles 2. must also be combined with production facilities of the company
Spare parts / Repairs	Long-term supply security (spare parts)	

Table 14: Criterion for substitution – product determined

Decision criterion relevance	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment reserve	10%	10%	10%	10%	10%	10%	8%	5%	5%	5%	5%	3%	1%	1%	1%
Amortization	10%	10%	9%	5%	5%	5%	5%	5%	4%	3%	3%	2%	2%	2%	2%
Introduction of substitution - share of sales	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	20%	40%	55%	75%	75%
Technology development	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Customer participation	0%	0%	1%	5%	5%	5%	7%	10%	11%	12%	12%	18%	20%	20%	20%
Old projects / product cycles	75%	75%	75%	75%	75%	75%	75%	75%	75%	70%	55%	35%	20%	0%	0%
Spare parts / Repair	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	2%	2%	2%	2%

Table 15: Decision criterion relevance for substitution - product determined

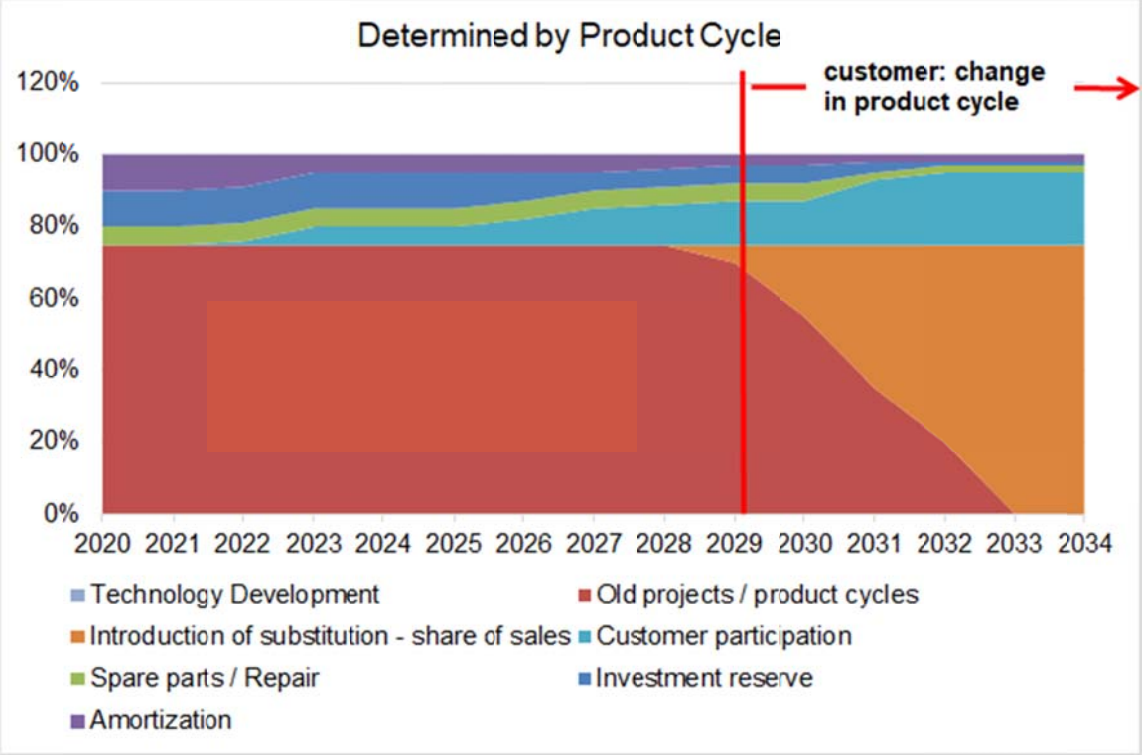


Fig. 8: Time span to realize substitution – product determined

3.1.7 **Timetable - customer driven (mainly smaller companies)**

Scenario 3	Determined by Customer
Small companies: 10 - 50 EMPL; Turnover: € 1 - 5 million	Substitution is determined by the resources of the company. The company is dependent on its customers, often has many individual customers and a very wide range of products. Their use is often not known. Customer involvement is crucial to maintain the production reliability of the companies.

Decision criterion	Description	Varying parameters
Investment reserve	target figure: € 250.000 for Cr(III) Turnover: €1 - 2 million; investment reserve 2%; duration: 12.5 years	1. investment costs 2. variation in turnover
Depreciation / Amortization	Useful life or tax depreciation	1. useful life: necessary repairs and additions 2. date of commissioning
Introduction of substitution - share of sales	When can the company plan the changeover?	1. secure conversion: chemical suppliers 2. securing customers
Technology development	Technology must be secure	
Customer participation	Mandatory for supply security Customer participation must accompany the changeover process	1. customer readiness 2. customer know-how
Old projects / product cycles	Until conversion, the company must continue to produce The current product cycles must be served	1. vary the duration of product cycles 2. must also be combined with production facilities of the company
Spare parts / Repair	Long-term supply security (spare parts)	

Table 16: Criterion for substitution – small companies

Decision criterion relevance	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment reserve	40%	40%	40%	37%	30%	25%	20%	10%	5%	0%	0%	0%	0%	0%	0%
Amortization	10%	10%	10%	5%	5%	5%	5%	5%	5%	5%	4%	3%	1%	0%	0%
Introduction of substitution - share of sales	0%	0%	0%	4%	10%	20%	27%	38%	54%	60%	73%	75%	82%	89%	94%
Technology development	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Customer participation	30%	30%	30%	34%	40%	40%	40%	40%	30%	30%	20%	20%	15%	10%	5%
Old projects / product cycles	15%	15%	15%	15%	10%	5%	3%	2%	1%	0%	0%	0%	0%	0%	0%
Spare parts / Repair	5%	5%	5%	5%	5%	5%	5%	5%	4%	4%	3%	2%	2%	1%	1%

Table 17: Decision criterion relevance for substitution – small companies

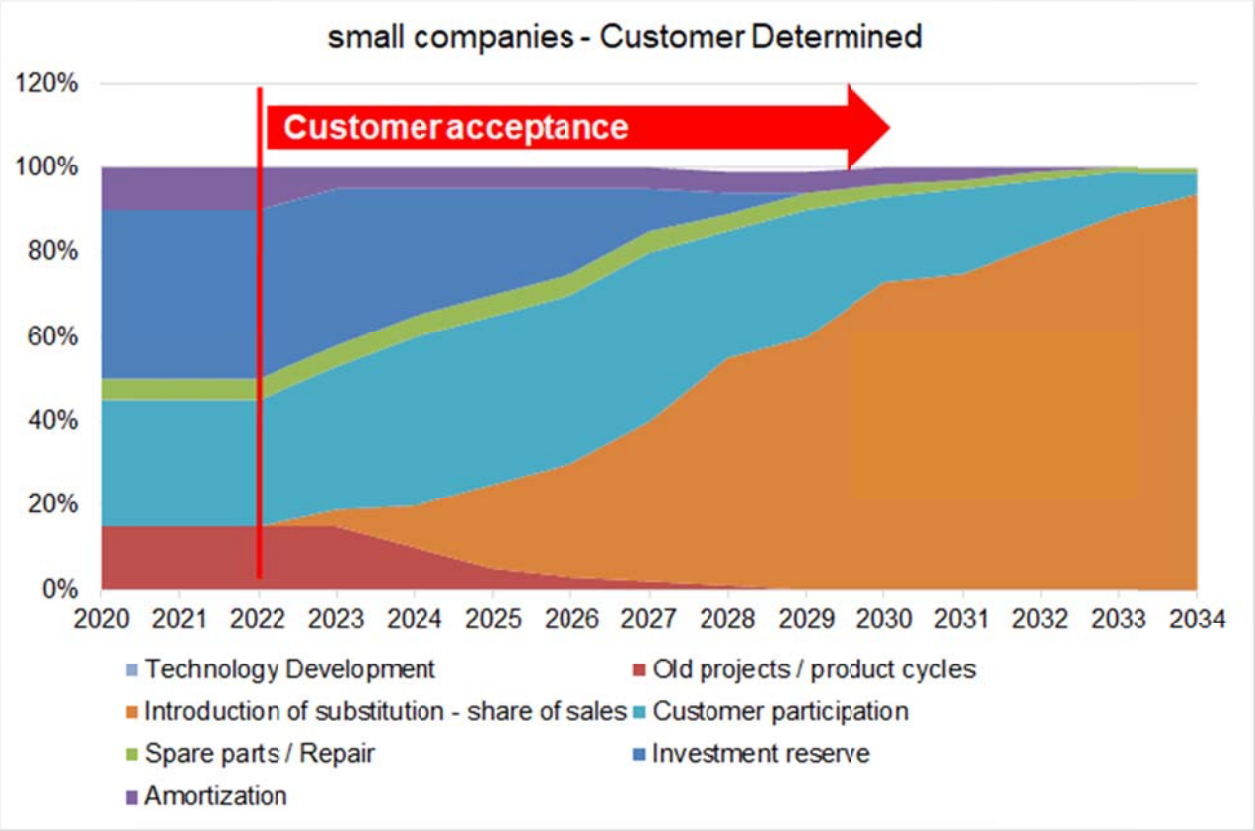


Fig. 9: Time span to realize substitution – small companies

3.1.8 Timetable - customers and products determined (mainly large companies)

Scenario 4	Customer and product determined
Large companies > 100 EMPl Turnover: > € 20million own products	The substitution is determined by the product range and its life cycles. The company often has large customers who have to accompany and approve the changeover. For them, the product is essential for a system product. Customer involvement is crucial, but is usually continuous. The companies often produce own products.

Decision criterion	Description	Varying parameters
Investment reserve	Target : € 0.5 million for Cr(III) Turnover: € 20 million; investment reserve 2%; duration: max. 2 years	1. investment costs 2. variation in turnover
Depreciation / Amortization	Useful life or tax depreciation	1. useful life: necessary repairs and additions 2. date of commissioning
Introduction of substitution - share of sales	When can the company plan the changeover?	1. secure conversion: chemical suppliers 2. securing customers
Technology development	Technology must be secure	
Customer participation	Mandatory for supply security Customer participation must accompany the changeover process	1. customer readiness
Old projects / product cycles	Until conversion, the company must continue to produce The current product cycles must be served	1. vary the duration of product cycles 2. must also be combined with the company's production facilities
Spare parts / Repairs	Long-term supply security (spare parts)	

Table 18: Criterion for substitution – large companies

Decision criterion relevance	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment reserve	10%	10%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Amortization	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Introduction of substitution - share of sales	0%	0%	5%	6%	11%	15%	25%	30%	35%	40%	45%	52%	60%	65%	65%
Technology development	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Customer participation	20%	20%	24%	24%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Old projects / product cycles	60%	60%	60%	60%	59%	55%	45%	40%	35%	30%	25%	18%	10%	5%	5%
Spare parts / Repair	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

Table 19: Decision criterion relevance for substitution – large companies

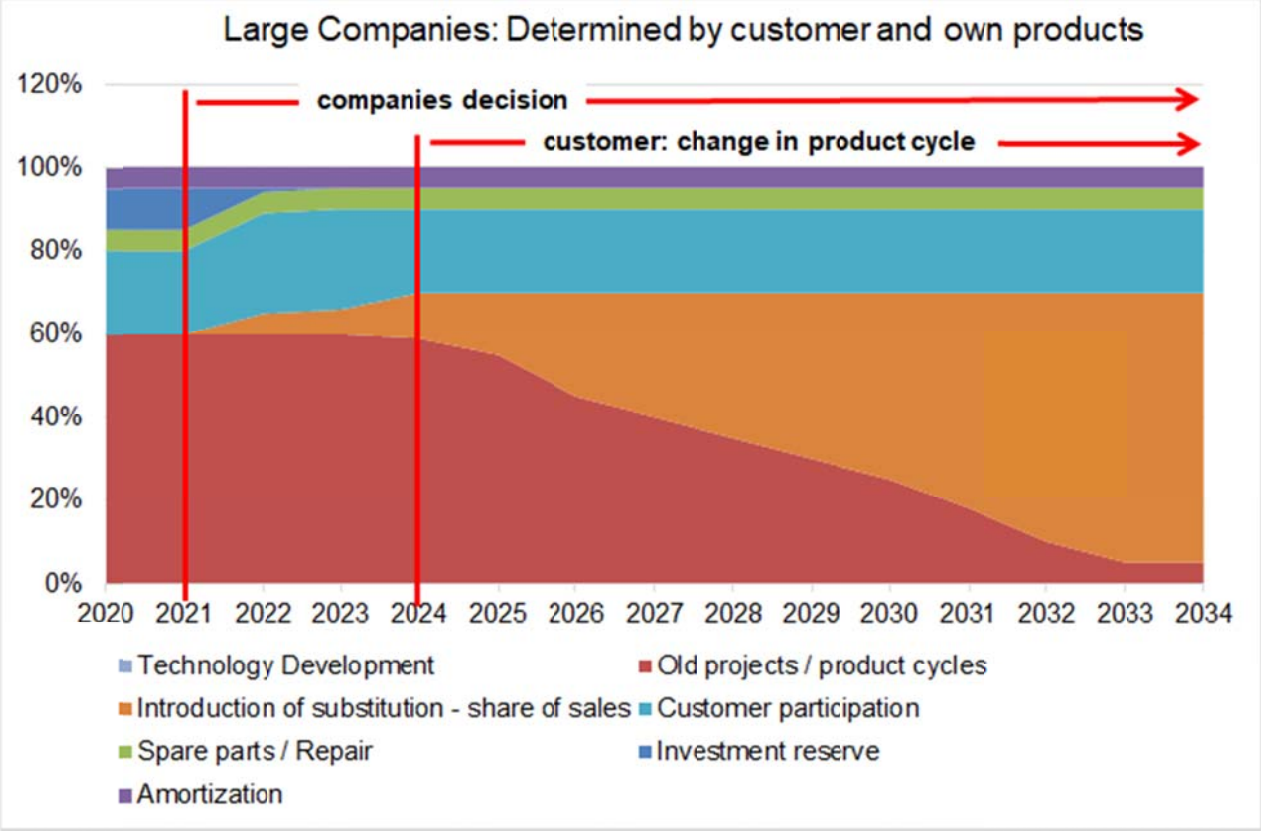


Fig. 10: Time span to realize substitution – large companies

3.2 Resulting R&D Topics

The pendent technological issues identified in section 2 are essential tasks for working on Scenario 1.

The following table is a compilation of the issues that will be jointly addressed by the participating companies in technological R&D projects within the framework of the VECCO Innovation Network in the coming years.

The results will also be discussed with customers in order to implement further substitution steps.

In addition, other, more fundamental projects will be carried out within the framework of the innovation network. For this purpose, an R&D roadmap has been drawn up which will be continued on an ongoing basis.

		TRL	Action
Decorative-functional			
	Cr(III) Technology		
	Colour scheme	7	R&D project
	Properties of the chrome layer	6	R&D project
	stability of the layer - abrasion and scratch resistance	6	R&D project
	Substrates to be coated	6	R&D project
	Hollow parts	4	R&D project
	pre-treatment	6	R&D project
	Approval	5	Customer contact
	Requirements for bath care	5	Contact chemical suppliers
	Development of additives, e.g. complex stabilisers	5	Contact chemical suppliers
	Coating capacity - Cr(III) is slower	5	R&D project
	Waste water treatment / environmental aspects	5	Contact chemical suppliers and disposal companies
	Pre-treatment various substrates, especially plastics		
	Benchmark for the available technologies		R&D project
	Process development on pilot plant		Evaluate production conversion possibilities
	Analysis of reaction mechanisms		Generate information
	Adjustment of process management		Generate information
	Analysis of technology for multi-component parts		Adapt to future substrates

Black Chromium			
	Cr(III) Technology		
	Properties of the chrome layer	6	R&D project
	stability of the layer - abrasion and scratch resistance	6	R&D project
	Hollow parts	4	R&D project
	Approval	5	Customer contact
	Requirements for bath care	5	Contact chemical suppliers
	Development of additives, e.g. complex stabilisers	5	Contact chemical suppliers
	Coating capacity - Cr(III) is slower	5	R&D project
	Waste water treatment / environmental aspects	5	Contact chemical suppliers and disposal companies
	PVD and Paint		
	Properties of the chrome layer	6	R&D Project : Homogeneity and reflectivity
	stability of the layer - abrasion and scratch resistance	6	R&D project: Adhesion and thermal stability
	Throughput and capacity	6	Production development
Hard - functional			
	Cr(III) Technology	**5**	
	Properties of the chrome layer:	5	R&D project
	Substrates to be coated:	5	R&D project
	Hollow parts	4	R&D project
	Approval		Customer contact
	Requirements for bathroom care:	5	Contact chemical suppliers
	Development of additives, e.g. complex stabilisers	5	Contact chemical suppliers
	Coating capacity - Cr(III) is slower	5	R&D project
	PVD	**9**	
	Part spectrum		Customer contact
	Rework	6	R&D project
	stability of the layer - abrasion and scratch resistance	6	R&D Project: Adhesion and thermal stability
	Salt bath nitriding	9	
	Capacities		Customer contact
	Stability	8	R&D project
	Thermal spraying	9	
	Particle homogeneity and size	6	R&D project

Anodising (Special)			
	Materials: Open porosity and high Si content	6	R&D project
	Defined roughness	6	R&D project
Stainless Steel Colouring (Special)			
	Colouring due to the precipitation of heavy metals	5	R&D project
	Introduction of metals into the surface by means of electrolysis	5	R&D project
	Colouring of nickel with HF (hydrofluoric acid)	5	R&D project

Table 20: R&D Topics for successful substitution

Key R&D areas	First R&D topics	Specific technology / R&D approach	Challenges	Application fields
Electro-chemical plating processes "Electroplating"	Cr(III) based functional chrome plating - electrochemical deposition of Cr from trivalent chromium compounds	Process kinetics	understanding and controlling boundary processes	
		Optimisation of layer build-up		
		Electrolyte development	process bath stability	
	Improvement of properties of Cr(III) based coatings	Influence of substrate properties	Metal matrix composite coatings not possible in chromium plating today	
		Micro-structures		
		Substrate variations		
		Coating layer composition		
		Integration of nano-sized particels		
	Improvement of properties of other electrochemical coatings	Nano-crystalline cobalt phosphorous alloy (CoP) coating		
		pulse plating or electroless plating - (auch NiPCo) coating		
		Ni and Ni metal matrix composite coatings (Ni-B, Ni-P; Ni-W)		
		Electroless or electrochemical deposition		
	Production Engineering			

Key R&D areas	First R&D topics	Specific technology / R&D approach	Challenges	Application fields
Physical plating processes	Laser cladding	EHLA process (extreme high-speed laser material deposition)	Process optimisation, esp. surface roughness	Coating of piston rods and other rotationally symmetric parts (limited length)
			Application development	
	HVOF High velocity thermal spraying / Plasma spraying	combination with inductive heating to improve caoting properties	Application development, suitability for further products	Coating of large scale cylinders (e.g. paper rollers)
			reduction of process costs	
			Process optimisation, esp. surface roughness	
	Case hardening	Salt bath nitriding		
		Salt bath nitrocarborising		
		Plasma nitriding		
	CVD / PVD special applications	CVD tungsten carbide/tungsten metal matrix composite coatings		Aerospace
	Production Engineering			
Combined (electro-) chemical / physical coating	Electroplating + CVD layer	DLC layer applied with CVD process	High process temperature of CVD proces; reduction of process costs	
	Electroplating + PVD layer	Ni and Ni alloy coatings (Ni-B, Ni-P; Ni-W) + PVD of TiN / TiCN / TiAlN	reduction of process costs	
	Production Engineering			

Key R&D areas	First R&D topics	Specific technology / R&D approach	Challenges	Application fields
Integration of innovative plating technologies with smart manufacturing / Industry 4.0 concept	Digitalisation of materials data	Digital materials data infrastructure of functional coatings value chain; simulation tools to predict performaces of new coating systems	Complexity of interdependencies between substrate microstructures, pre-treatment and coating processes	
	Data Mining based solutions to process optimisation			
	Sensor systems, advanced analytics			
	Optimisation of resource efficiency, environmental / safety performance of processes over value chain	Life-Cycle Analysis		
		Life-Cycle Optimisation		
	Flexible, efficient production of small lot sizes	e.g. plating of 3D printed metal / plastic parts		
Optimized business processes + communication in the supply chain	Data / information exchange	Cloud solutions		
	Smart services	chemicals and risk management		
		monitoring + analytics		
	New business models			
	Development of demonstration projects			
	Investment support	...		

Table 21: R&D Roadmap

3.3 Innovation network in the surface technology industry – authorisation holder hapoc / VECCO

(Please refer to Appendix 2 – sec. 6.2.)

The objective is to provide a European framework to foster understanding, development, and actual substitution of Cr(VI) in industrial supply chains.

To set up a cooperative innovation network to develop, assess and implement technologies for surface technology industry and to support the implementation of approved technologies for specific uses. Key issues addressed by the cooperative network will be

- To involve all relevant stakeholders – technology suppliers, plating service providers, downstream customers, associations and public sector actors- of the supply chain in the joint development initiative.
- To set up specific R&D projects both for technological development of individual applications and to assess and mitigate socio-economic issues and risks.
- To develop and continuously review parameters for the targeted evaluation of technologies.

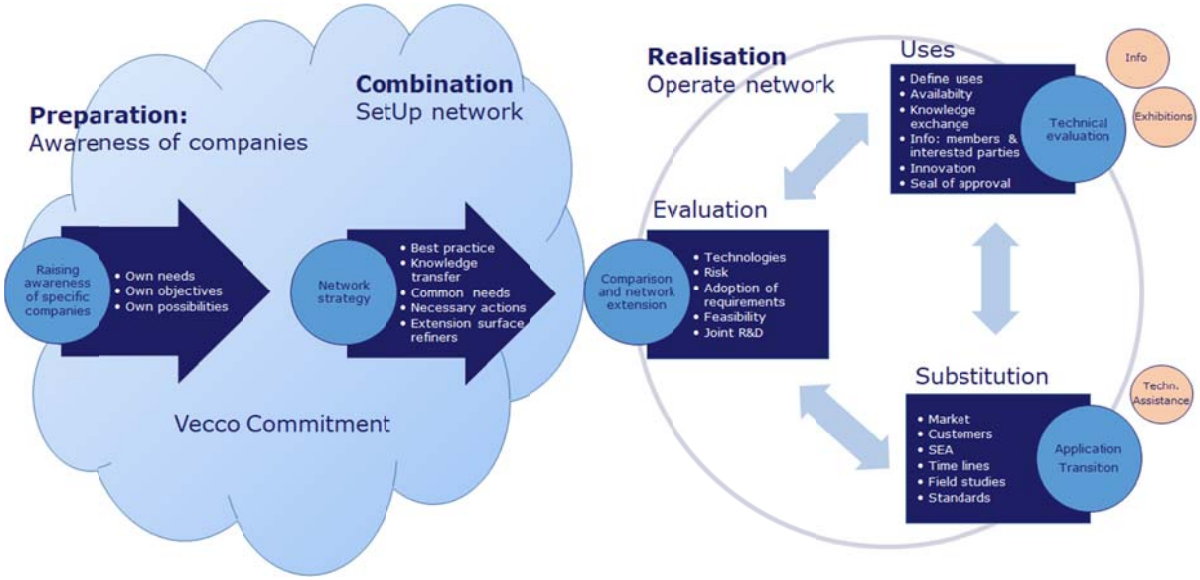


Fig. 11: General structure of VECCO innovation network to support substitution

Innovation, substitution in the context of REACH authorisation

The REACH authorisation process provides the catalytic element to bring the above network into being under the cooperation of Vecco and the other network partners. Vecco is both the guarantor of the process and the central lynchpin of the substitution innovation but also the key holder for the supply of Cr (VI) where substitution is not possible. There is thereby a balance between the need to be flexible, adapt, innovate and give adequate time to implement. Furthermore there is increasing need to justify the continued use within the context of the authorisation. In this manner the substitution plan requirement within the REACH regulation becomes the driver to support the change of European business towards

The resulting substitution plan is summarized in Table 26

Innovation, substitution in the context of REACH authorisation

The REACH authorisation process provides the catalytic element to bring the above network into being under the cooperation of Vecco and the other network partners. Vecco is both the guarantor of the process and the central lynchpin of the substitution innovation but also the key holder for the supply of Cr (VI) where substitution is not possible. There is thereby a balance between the need to be flexible, adapt, innovate and give adequate time to implement. Furthermore there is increasing need to justify the continued use within the context of the authorisation. In this manner the substitution plan requirement within the REACH regulation becomes the driver to support the change of European business towards

3.4 Timetable of actions

3.4.1 Introductory remarks – general activities VECCO / hapoc

hapoc and VECCO support the work of the companies for a successful substitution.

Their task is to determine and distribute information about the available technologies and to evaluate their applicability.

To this end, the work packages listed below are already being actively processed and further intensified.

The focus will be on the further development of IT-based tools.

The resulting time schedules can be found in sec. 3.4.3.

Section 1: General tasks
WP 1: Analysis and evaluation of alternatives
1.1 Literature research
1.2 R&D support
WP2: Contact and cooperation with customers
2.1 Discussion and presentation
2.2 Organisation of field trials
WP 3: Evaluation of specific products (in combination with WP2)
3.1 Selection and test
3.2 Decisions
WP 4: Market analysis
4.1 EU market
4.2 Non EU market
4.3 Monitoring market developments
Section 2: Innovation Network
WP1: Technological Roadmap and projects relevant for companies
1.1 Literature research
1.2. Definition requirement of the companies
WP2: Contact and cooperation with interested parties
2.1. Discussion and presentation
2.2. Target definition and agreement
WP 3: Evaluation of technologies
3.1. Details of technologies (based on roadmap)
3.2. Risk analysis
3.3. Adoption of requirements
3.4. Feasibility
WP 4: Evaluation of uses / utilisations
4.1. Define uses / utilisations
4.2. Availabilitiy of relevant technologies
4.3. Knowledge exchange
4.4. Infomation of members and interested parties

WP 5: Evaluation of requirements for substitution
5.1. Market acceptance
5.2. Requirements of customers
5.3. Cooperation field studies
5.4. Error analysis
5.5. Definition of standards and necessary certifications
Section 3: Support of companies substitution
WP 1: Evaluation of companies requirements
1.1. Evaluation of sections 1 and 2 in terms of companies requirements
1.2. Definition of companies possibilities
WP2: Development of adequate IT Tools
2.1. Further development of risk analysis and compliance check
2.2. Development of product database for substitution requirements
WP 3: Information
3.1. Regular webinars / seminars
3.2. Annual publications
WP 4: Staff training - Further training
4.1. Internal qualification based on specific requirements of companies
4.2. External continuing education - information about technological development

Table 22: Working packages for support and innovation network

3.4.2 Introductory remarks – companies actions

As already mentioned in the introductory sections, the question of substitution possibilities in the hapoc application can only be answered by dividing the total of applications into subgroups. First of all, the classification must be made as we have done in the previous sections:

1. **Decorative-functional (incl. Pre-treatment)**
2. **Black chrome**
3. **Functional – Hard chrome**
4. **Further applications (Anodizing, Colouring stainless steel)**

The possibilities for downstream users differ considerably. While the technical possibilities are relatively advanced for groups 1.-2., such a 1/1 alternative is still a long way off for functional hard chrome plating. It can be stated that for specific applications there are alternatives which are already being used successfully both globally and in Europe. What all these technologies have in common, however, is that they do not work technically in other application groups. An implementation of the SAGA concept is therefore only possible in more specific subgroups. We have carried out the evaluation of the subgroups (for details see sec. 6.2 – appendix 1). It should also be noted here that in some utilisations, despite existing alternatives, only partial areas can be technically substituted.

In assessing the available alternatives, we have found in all 4 groups that for the coating companies, the electroplating operations are best implemented from commercial and technical

aspects ("technical and economically feasible"). In many cases, baths and peripherals can be integrated into the existing structure and the electroplating know-how is available in the company. Therefore we have prioritised these technologies in the presentation for the hapoc application.

For the sake of completeness, we have presented the substitution plans for the other technologies also.. Implementation will only be possible for specific companies or large groups of companies that have the appropriate size and structures.

The resulting criteria for the applications are summarized in secs. 3.4.4 to 3.4.7.

The general structure for evaluation and implementation is as follows:

The first step is the concentration on the Cr(III) Technologie **Evaluation of Cr(III) Technology**	
WP 1: Analysis for specific utilisations	
1.1. Group 1	Analysis of requirements
1.2. Group 2	
1.3. Group 3	
1.4. Group 4	
1.5. Group 5	
1.6. Group 6	
1.7. Group 7	
1.8. Group xxxx	
WP 2: Major technological challenge: substrate	Are special issues given?
2.1.substrates	To be defined
2.2. Environment	
2.3. Technologies	
2.4. …	
Further procedure, if alternative generally available **What have to be done to implement?**	
WP3: Contact and collaboration with customers	
3.1. Discussion and presentation	Contact and information
3.2. Field test with customers	Joint tests
3.3. Error analysis	What can go wrong?
3.4. Certification	Release
3.5. Customers acceptance	
WP 4: Organisational and logistical change	
4.1. Project planning	Planing the implementation taking company specific problems into account
4.2. Customer orders	
4.3. Financing / Investment / Funding	
4.4. Approval from authorities and customer	
4.5. Construction of the plating line	
4.6. Sampling and field trials	
4.7. Final approval and Release	

WP 5: Technical implementation and further development	
5.1. Planning for installation of a Cr(III) line	Technical implementation
5.2. Positioning of electrolytes	
5.3. Testing and adjustment of electrolytes to the utilisations	
5.4. Further development of the process	
5.4.1. Analysis	
5.4.2. Adjustment of process management	
5.5. Production-related conversion	
WP 6: Adaptation of chemicals used - Cooperation with chemical suppliers	
6.1. Supporting electrolyte: utilisation of boric acid, etc - alternatives?	Identifying topics for further development
6.2. Additives (e.g. complexing agents)	
6.3. Testing and piloting	
WP 7: Market-economy implementation - new customer projects	
7.1. Transition from pilot projects (selected series)	Analysis of market requirements
7.2. Launching of new projects using Cr III	
7.3. Review of existing Cr III capacity	
7.4. Industrialise customer projects	
WP 8: Internal Staff training (in cooperation with VECCO)	
8.1. Technical qualification	Qualification of employees
8.2. External continuing education	
Further procedure, if alternative not generally available	
WP 9: Further R&D (in cooperation with VECCO)	
9.1. Definition of utilisations	Identifying specific R&D for the utilisation
9.2. Definition of insufficiently achievable conditions	
9.3. SetUp Joint R&D Projects2	
9.4. Contact with technology providers	

Table 23: Working packages for evaluation of Cr(III) Technology for the different applications

The evaluation of the applicability of the Cr(II) Technology then is followed by the evaluation of other technologies. The evaluation will be carried out in the same mannor.

Second step: Evaluation of other adequate technologies to be taken into account.
WP 1: Analysis for specific utilisations
1.1. Group 1
1.2. Group 2
1.3. Group 3
1.4. Group 4
1.5. Group 5
1.6. Group 6
1.7. Group 7
1.8. Group xxxx

WP 2: Major technological challenge: substrate
2.1.substrates
2.2. Environment
2.3. Technologies
2.4. …
Further procedure, if alternative generally available
WP 3: Contact and collaboration with customers
3.1. Discussion and presentation
3.2. Field test with customers
3.3. Error analysis
3.4. Certification
3.5. Acceptance of customers
WP 4: Organisational and logistical change
4.1. Project planning
4.2. Customer orders
4.3. Financing / Investment / Funding
4.4. Approval from authorities and customer
4.5. Construction of production facility
4.6. Sampling and field trials
4.7. Final approval and Release
WP 5: technical implementation
5.1. Decision: Establishment of an own construction facility
5.2. Adjustment of the process control (depending on utilisation)
5.3. Production-related implementation (depending on utilisation)
WP 6: Contact and cooperation with technology providers
6.1. Discussion and presentation
6.2. Field trials
6.3. Error analysis
WP 7: Internal Staff training (in cooperation with VECCO)
7.1. Technical qualification
7.2. External continuing education
Further procedure, if alternative not generally available
WP 8: Further R&D (in cooperation with VECCO)
8.1. Definition of utilisations
8.2. Definition of insufficiently achievable conditions
8.3. SetUp Joint R&D Projects
8.4. Contact with technology providers

Table 24: Working packages for evaluation of other technologies for the different applications

3.4.3 Timeline R&D and further overall actions – VECCO / hapoc

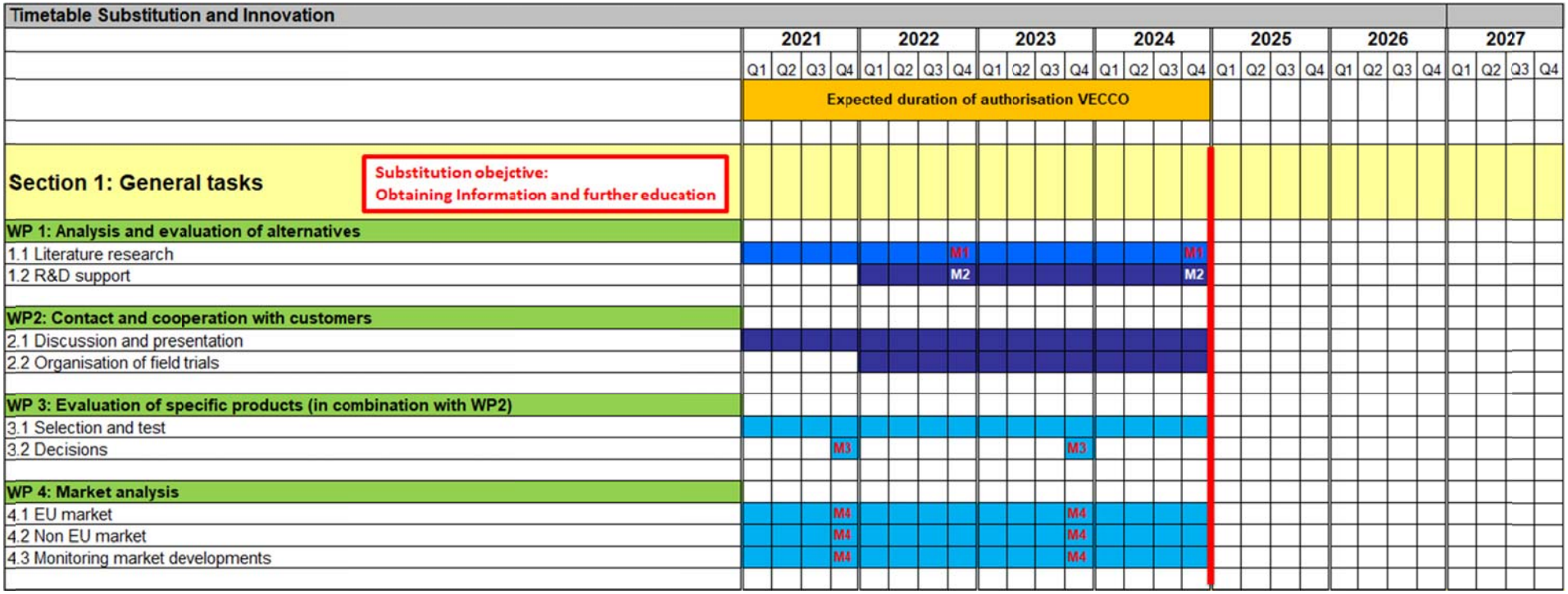


Table 25: Substitution plan hapoc / VECCO – General tasks

Timetable Substitution and Innovation	2021				2022				2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Expected duration of authorisation VECCO																											
Section 2: Innovation Network — Substitution objective: Technological innovation, analysis and evaluation																												
WP1: Technological Roadmap and projects relevant for companies																												
1.1 Literature research				M1								M1																
1.2. Definition requirement of the companies								M2								M2												
WP2: Contact and cooperation with interested parties																												
2.1. Discussion and presentation																												
2.2. Target definition and agreement								M3				M3				M3												
WP 3: Evaluation of technologies																												
3.1. Details of technologies (based on roadmap)								M4								M4												
3.2. Risk analysis								M4								M4												
3.3. Adoption of requirements								M4								M4												
3.4. Feasibility								M4								M4												
WP 4: Evaluation of uses / utilisations																												
4.1. Define uses / utilisations				M5				M5				M5				M5												
4.2. Availabilitiy of relevant technologies				M5				M5				M5				M5												
4.3. Knowledge exchange				M5				M5				M5				M5												
4.4. Infomation of members and interested parties				M5				M5				M5				M5												
WP 5: Evaluation of requirements for substitution																												
5.1. Market acceptance								M6								M6												
5.2. Requirements of customers								M6								M6												
5.3. Cooperation field studies								M6								M6												
5.4. Error analysis								M6								M6												
5.5. Definition of standards and necessary certifications																M6												

Table 26: Substitution plan hapoc / VECCO – Innovation network

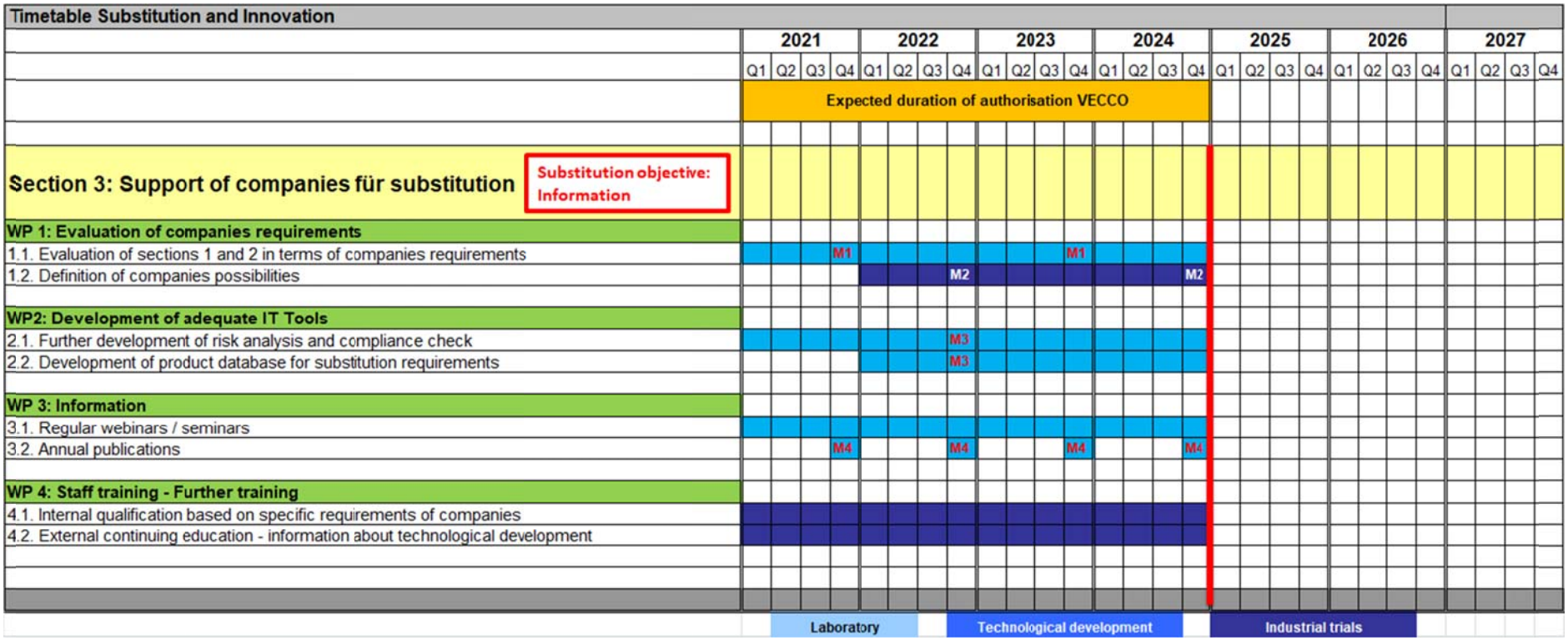


Table 27: Substitution plan hapoc / VECCO –Companies support

3.4.4 Timeline application decorative

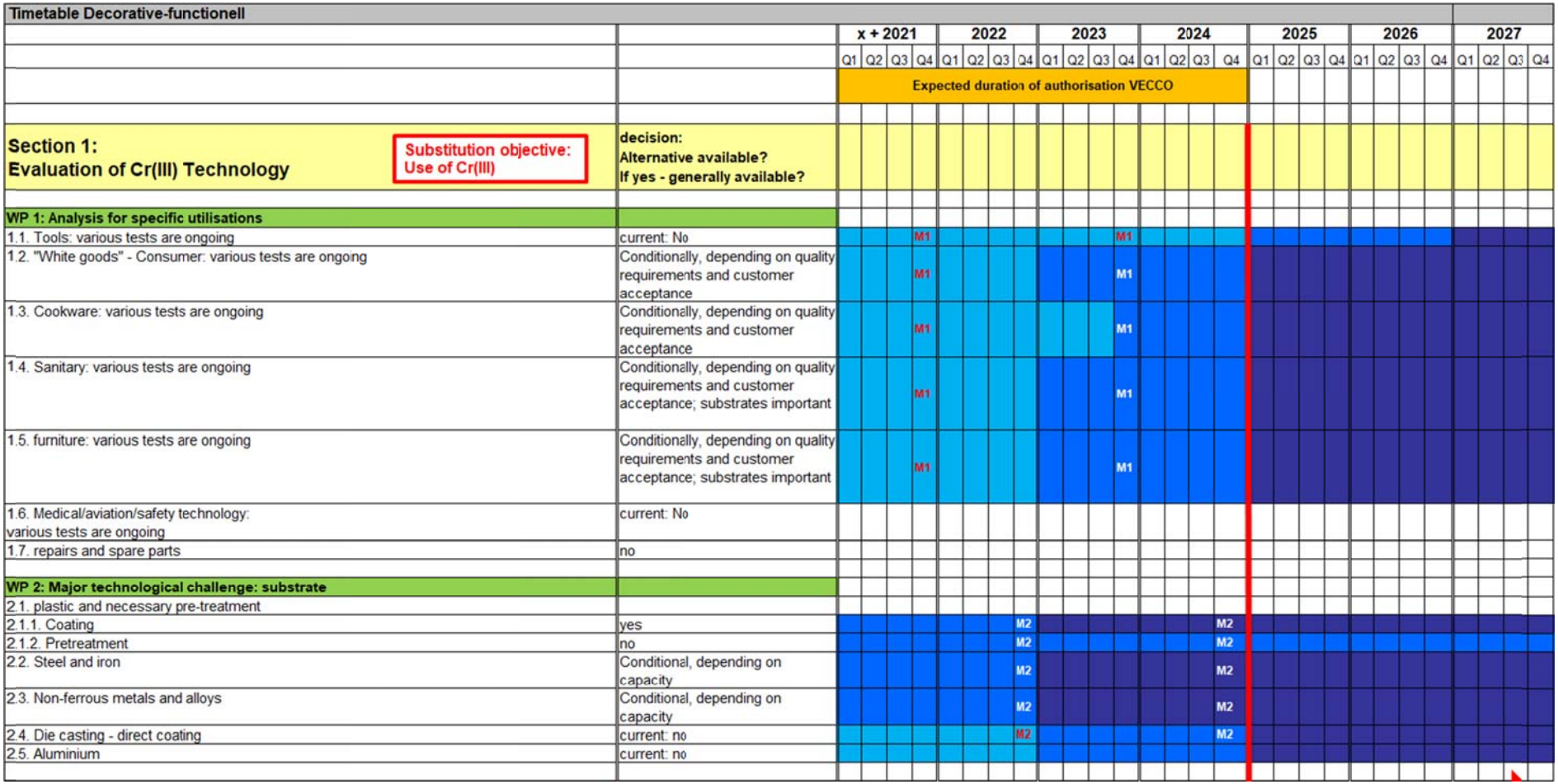


Table 28: Substitution plan decorative-functional – Evaluation Cr(III) Technology

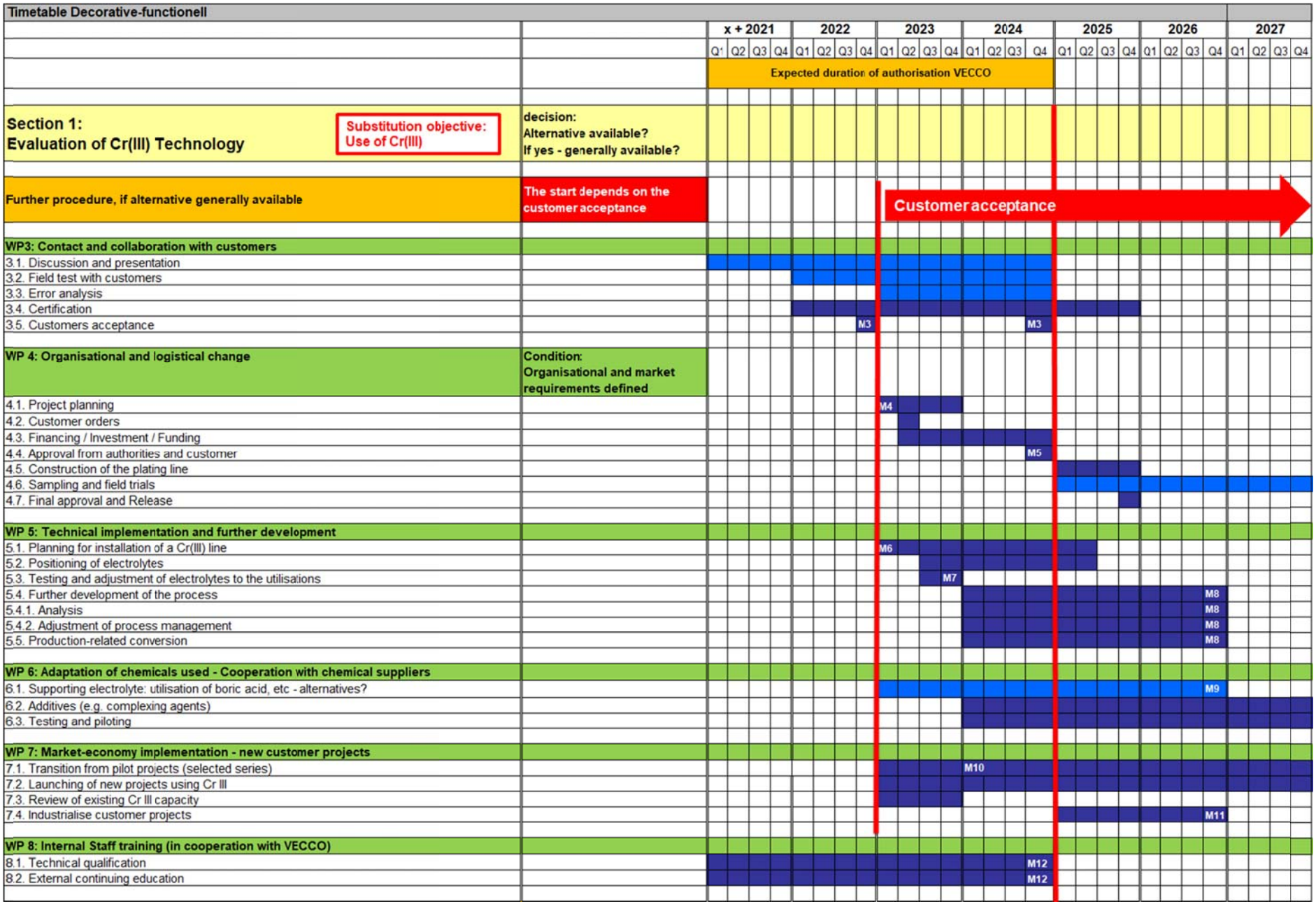


Table 29: Substitution plan decorative-functional –Cr(III) Technology generally available

Timetable Decorative-functionell		x + 2021				2022				2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Expected duration of authorisation VECCO																											
Section 1: Evaluation of Cr(III) Technology — Substitution objective: Use of Cr(III)	**decision: Alternative available? If yes - generally available?**																												
Further procedure, if alternative not generally available																													
WP 9: Further R&D (in cooperation with VECCO)	**see R&D Roadmap**																												
9.1. Definition of utilisations																	M13												
9.2. Definition of insufficiently achievable conditions																	M13												
9.3. SetUp Joint R&D Projects2																	M13												
9.4. Contact with technology providers																	M13												

Table 30: Substitution plan decorative-functional – Cr(III) Technology not generally available

Timetable Decorative-functionell		x + 2021				2022				2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Expected duration of authorisation VECCO																											
Section 2: Painting and PVD Substititon objective: Painting / PVD	**decision: Alternative available? If yes - generally available?**																												
WP 1: Analysis for specific utilisations																													
1.1. Tools: various tests are ongoing	current: PVD under special conditions				M1								M1																
1.2. "White goods" - Consumer: various tests are ongoing	PVD: No Painting: No				M1								M1																
1.3. Cookware: various tests are ongoing	PVD: No Painting: No				M1								M1																
1.4. Sanitary: various tests are ongoing	Conditionally, depending on quality requirements and customer acceptance; substrates important				M1								M1																
1.5. furniture: various tests are ongoing	Conditionally, depending on quality requirements and customer acceptance				M1								M1																
1.6. Medical/aviation/safety technology: various tests are ongoing	current: No																												
1.7. repairs and spare parts	no																												
WP 2: Major technological challenge: substrate																													
2.1. plastic and necessary pre-treatment	PVD: no (durability) Painting: quality requirements								M2								M2												
2.2. Steel and iron	PVD: no (durability) Painting: quality requirements								M2								M2												
2.3. Non-ferrous metals and alloys	PVD: no (durability) Painting: quality requirements								M2								M2												
2.4. Die casting - direct coating	PVD: no (durability) Painting: quality requirements								M1								M2												
2.5. Aluminium	PVD: no (durability) Painting: quality requirements																												

Table 31: Substitution plan decorative-functional – Evaluation PVD / Painting

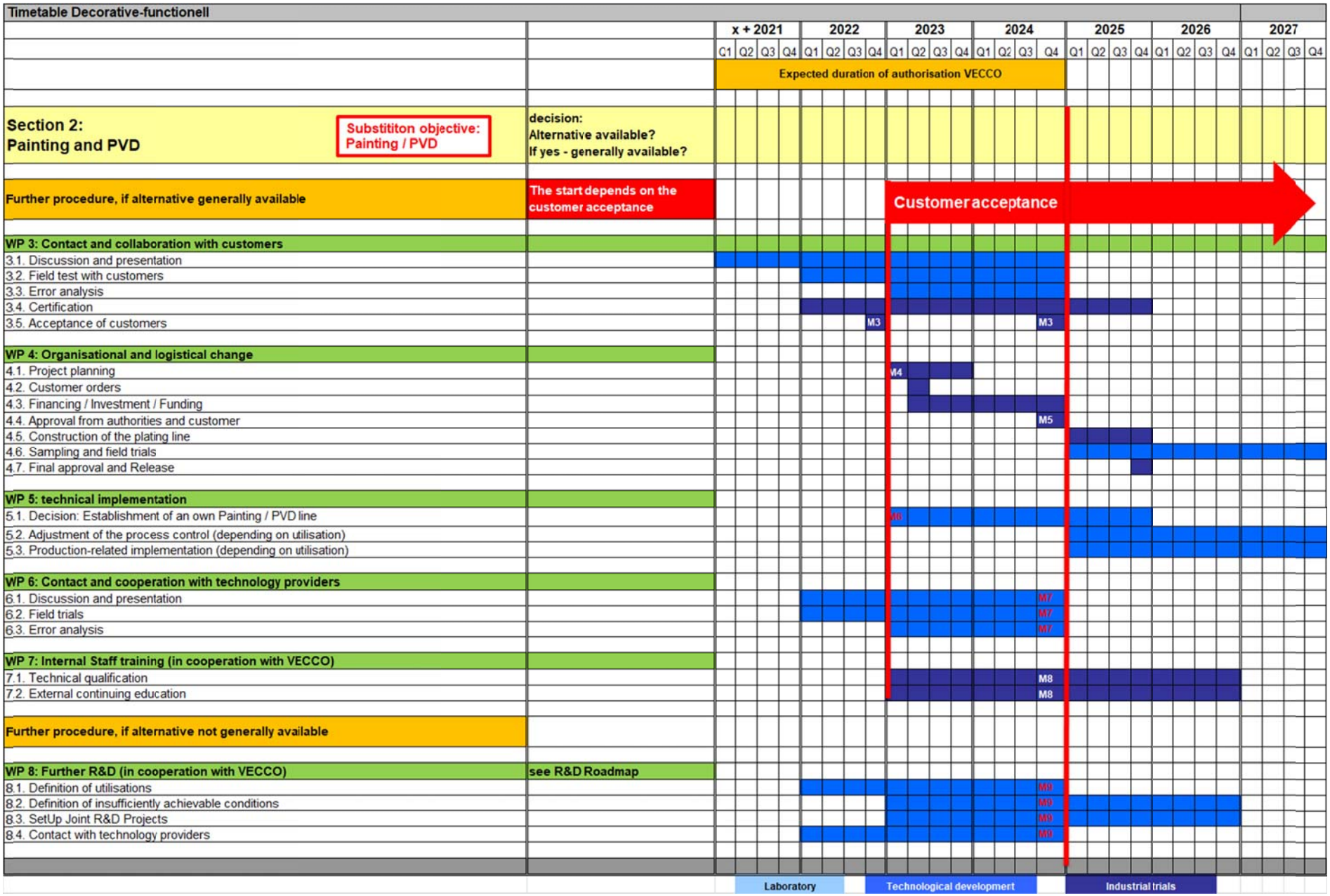


Table 32: Substitution plan decorative-functional – PVD / Painting availability

3.4.5 **Timeline application black chrome**

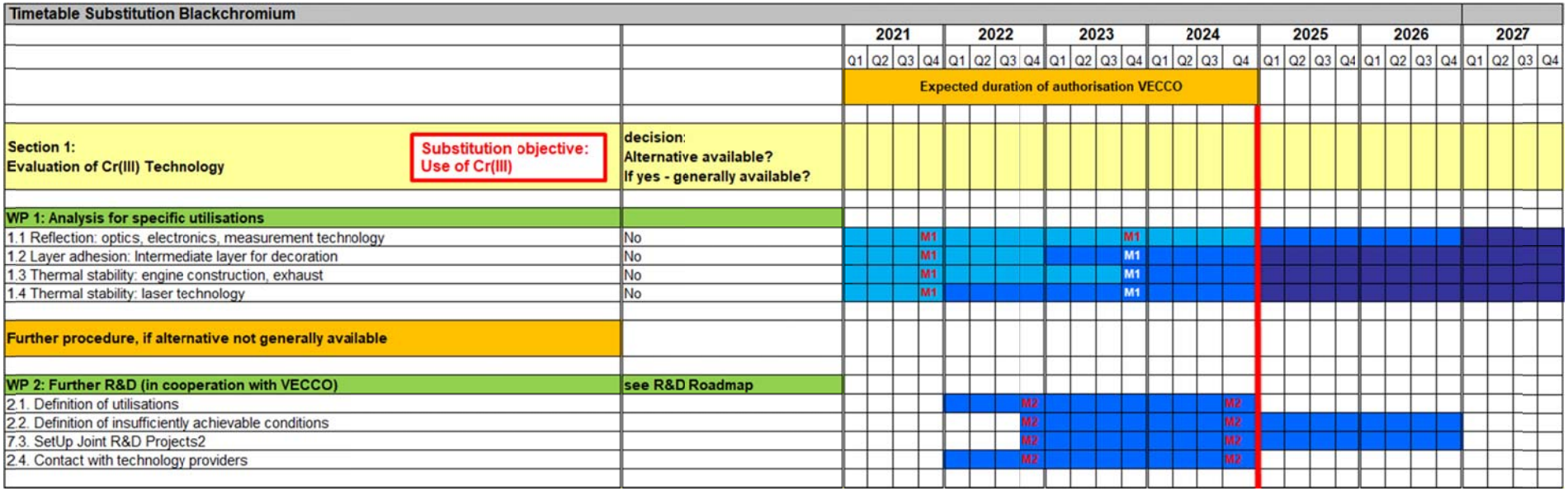


Table 33: Substitution plan Black chrome – Cr(III) Technology - evaluation

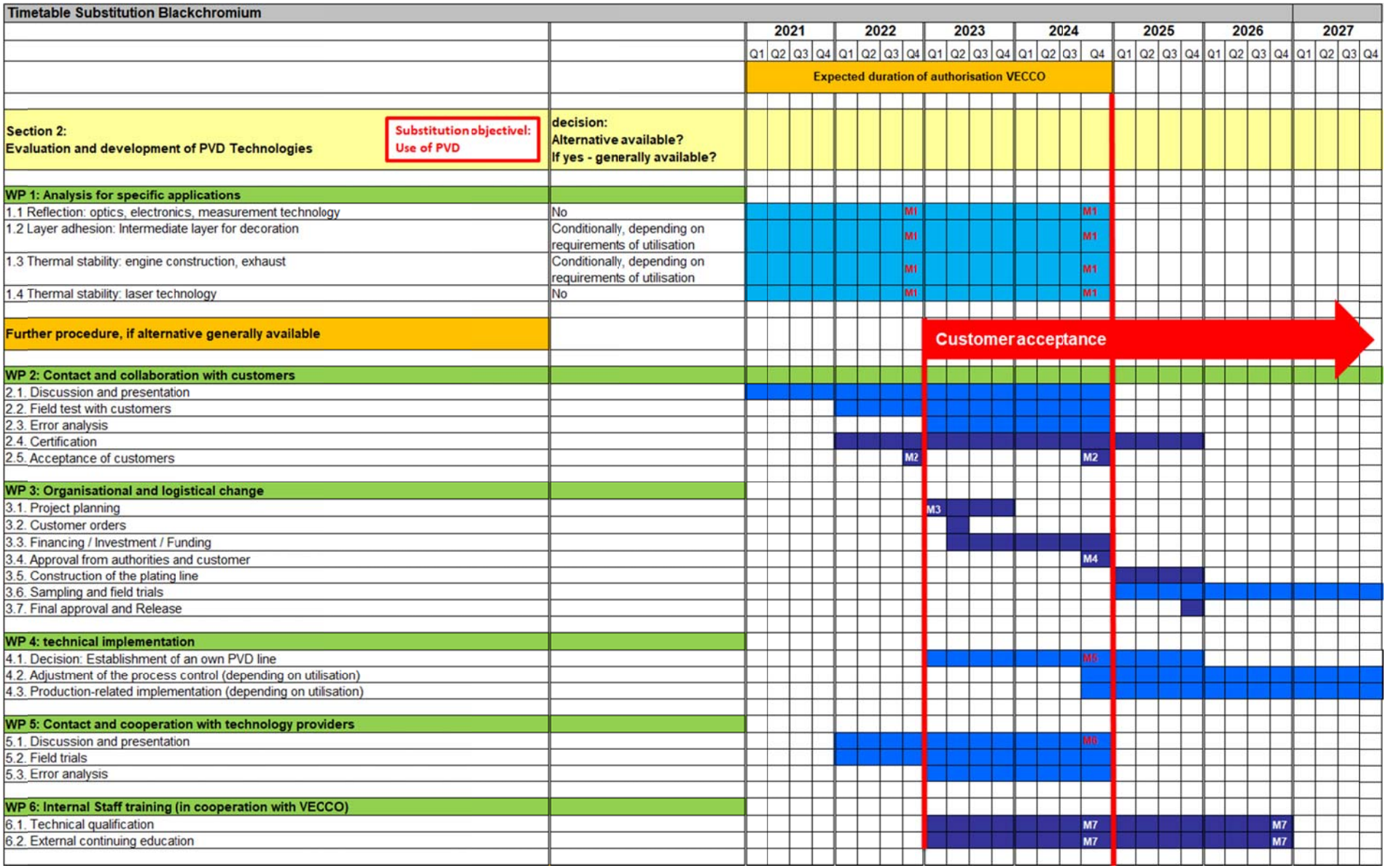


Table 34: Substitution plan Black chrome – PVD evaluation

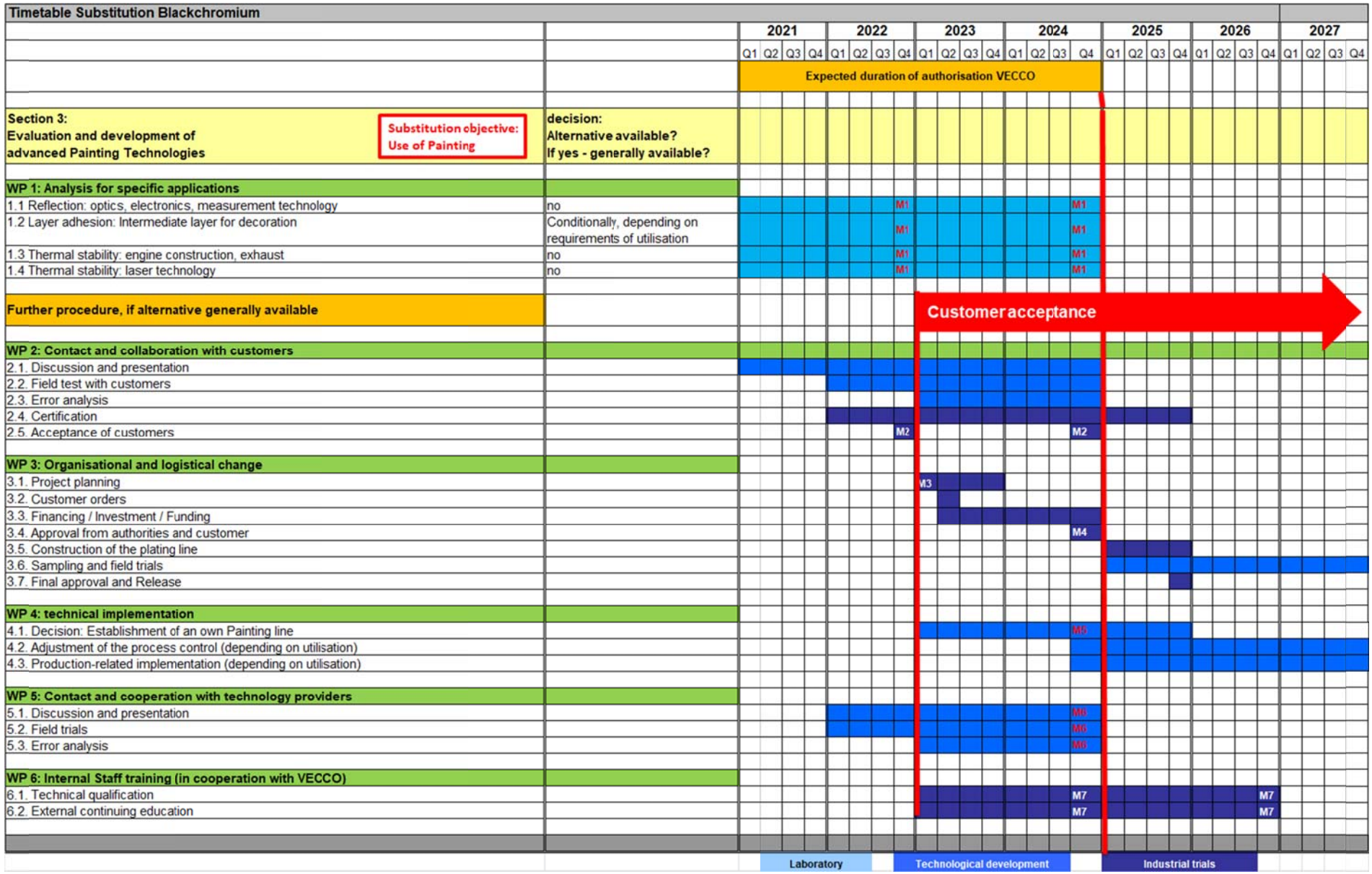


Table 35: Substitution plan Black chrome – Painting Evaluation

3.4.6 Timeline application functional Chromium

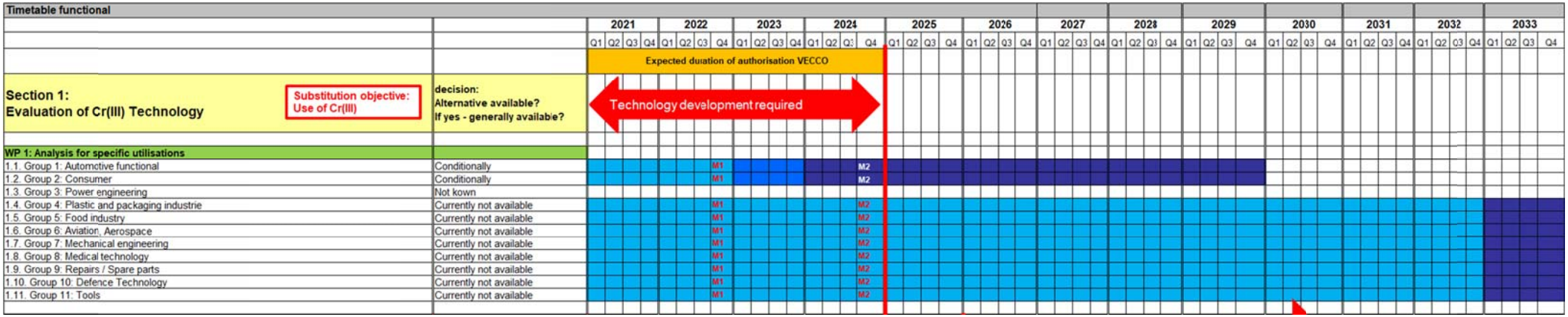


Table 36: Substitution plan functional – Evaluation Cr(III) Technology

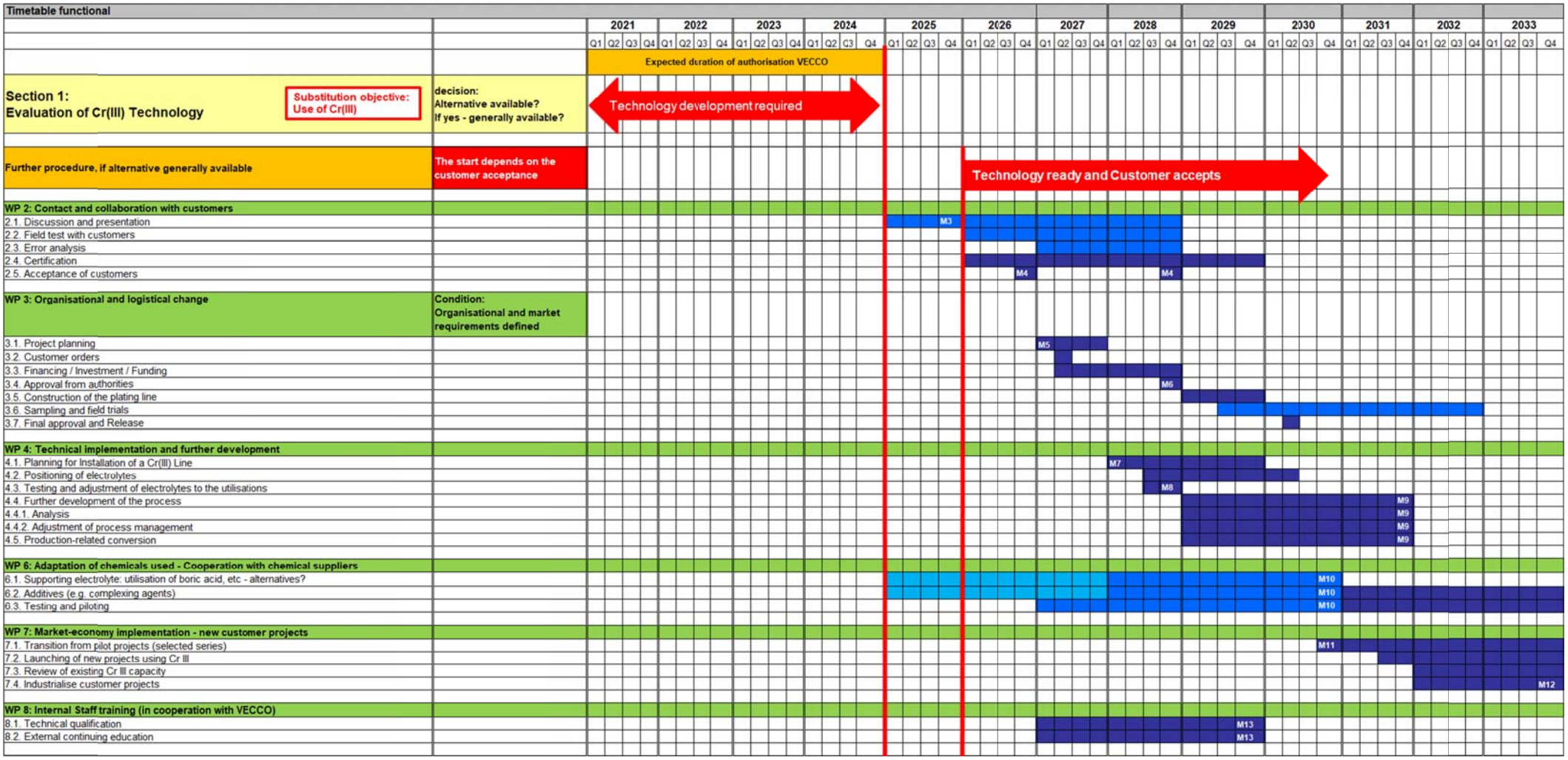


Table 37: Substitution plan functional – prerequisite: Cr(III) Technology generally available

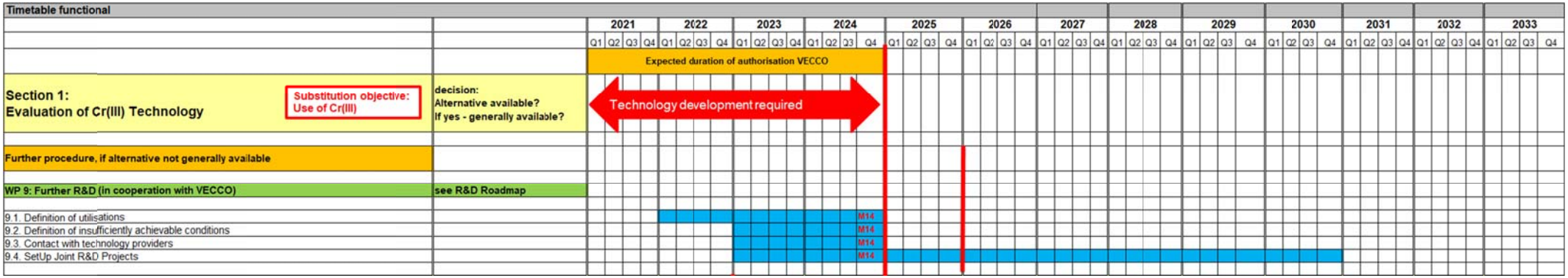


Table 38: Substitution plan – functional –Cr(III) Technology not generally available

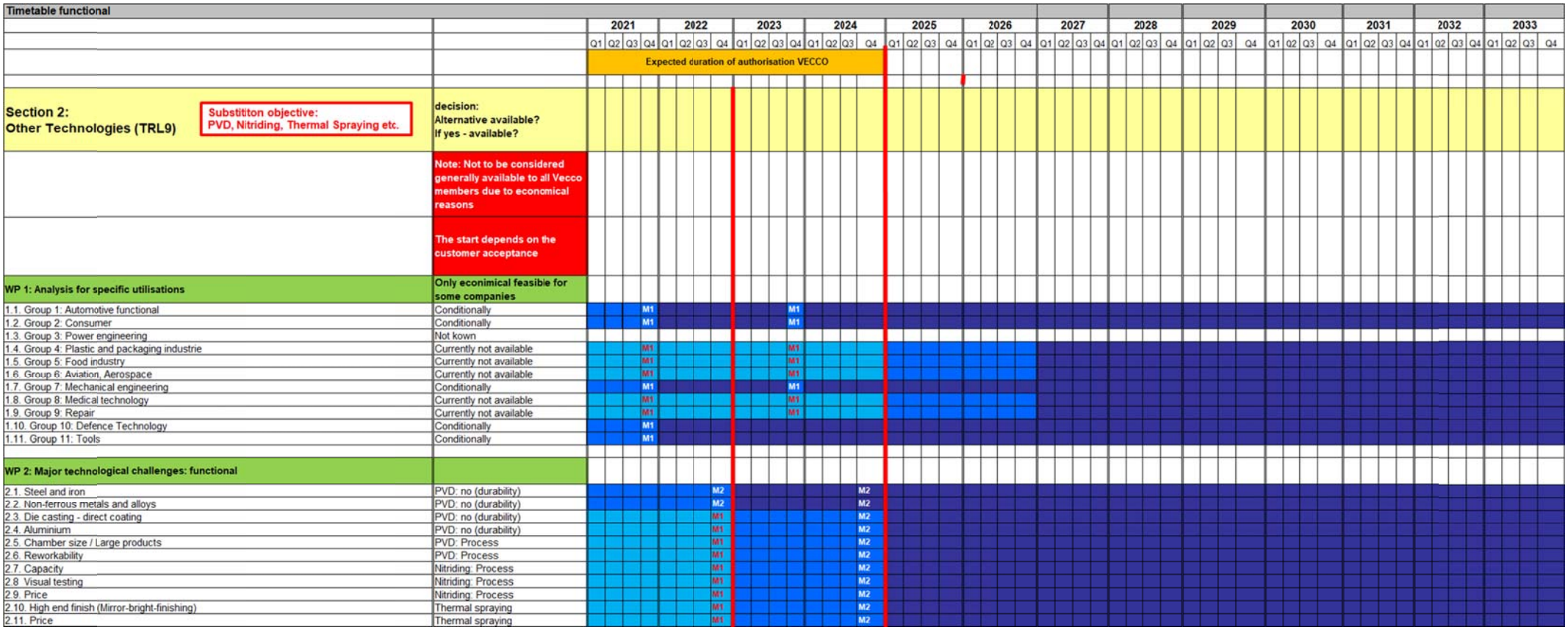


Table 39: Substitution plan functional – Evaluation other technologies

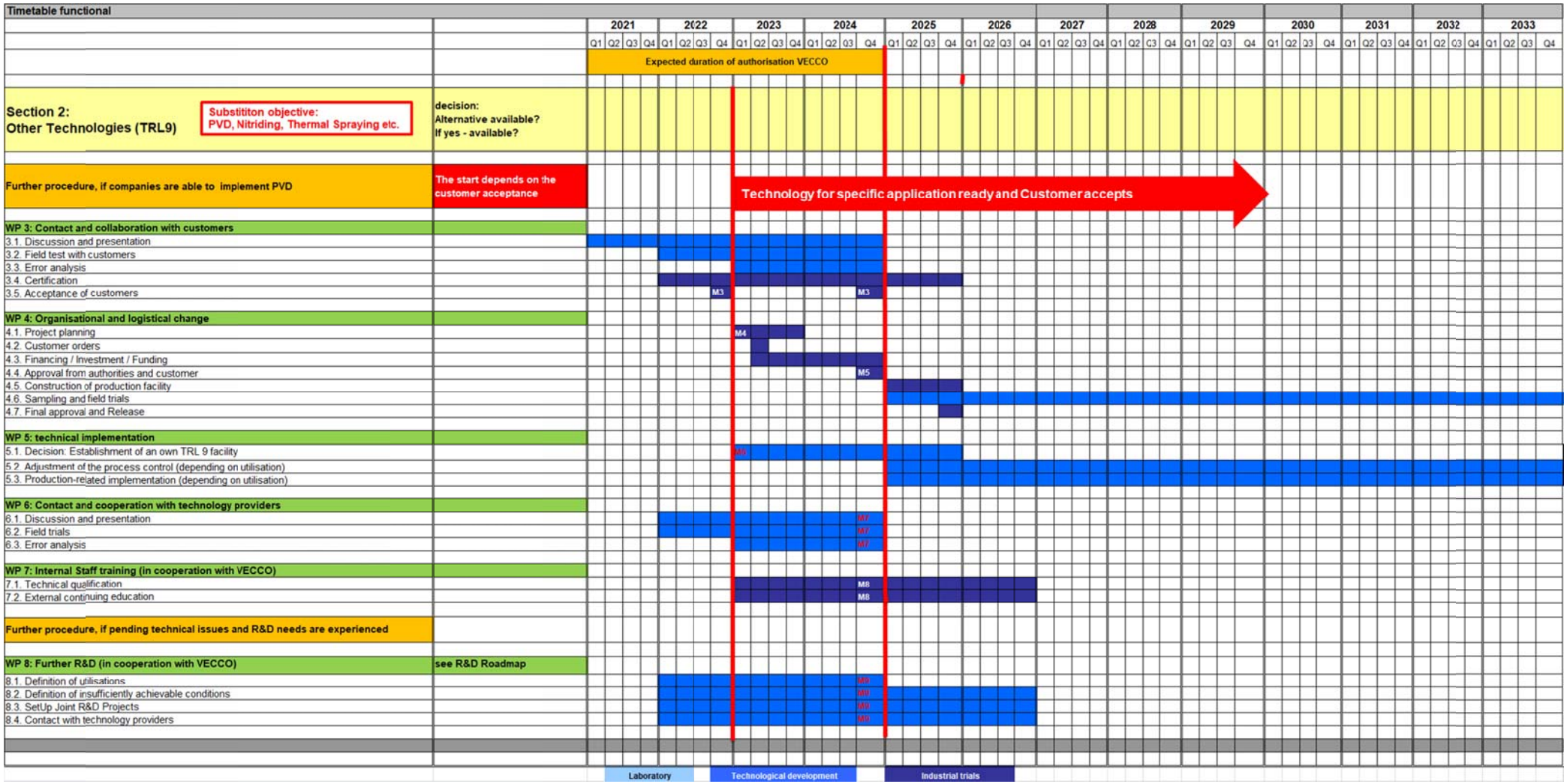


Table 40: Substitution plan functional – other techniques in special cases availability

3.4.7 Timeline special applications

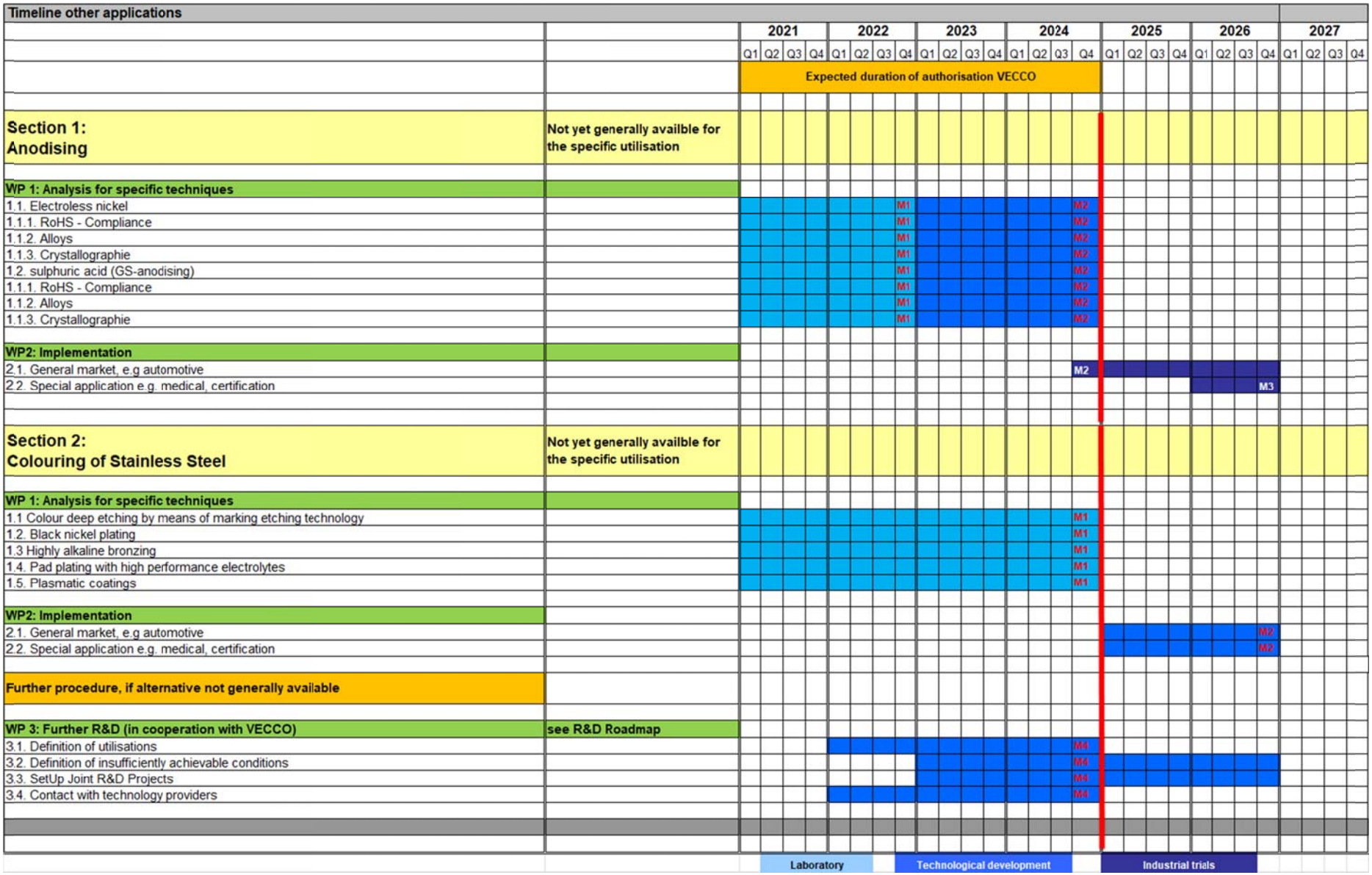


Table 41: Substitution plan special application

3.4.8 **Milestones**

1. Timeline Substitution and Innovation

a. General Tasks
- M1 Every two years summaries literature research
- M2 Every two years R&D reports
- M3 Every two years reports about product evaluation for substitution
- M4 Every two years reports of market development

b. Innovation Network
- M1 Compilation of the relevant topics
- M2 Discussion with the companies
- M3 Agreement on objectives
- M4 Annual monitoring of relevant projects
- M5 Annual presentation of product requirements
- M6 Annual market observations

c. Support of companies for substitution
- M1 Every two years summaries of companies requirements
- M2 Summary of companies' possibilities
- M3 Database established
- M4 Publications

2. Timeline Decorative-functional

a. Evaluation of Cr(III) Technology
- M1 Reports on the status of the utilities
- M2 Progress in substrate coating with Cr(III)
- M3 Customers Acceptance
- M4 Planning has begun
- M5 Permits issued for implementation
- M6 Technology can be produced in series
- M7 Cr III available on companies site
- M8 Technology can be produced in series
- M9 Can boric acid be dispensed?
- M10 Series production with secure supply to children is possible
- M11 About 90% of production converted
- M12 Employees qualified
- M13 Definition of R&D projects necessary for the implementation of Cr(III) technology

b. Pre-treatment
- M1 Assessment various technologies
- M2 Can multi-component parts be pre-treated? Can the system be regenerated? Can it be assured that the frames are not coated?
- M3 Is the serial implementation of multi-component parts feasible with the existing plants?
- M4 Can an alternative form of pre-treatment be sold on the market for all our parts?
- M5 Pre-treatment Zn die-casting or aluminium possible?

c. Evaluation Painting and PVD
- M1 Reports on the status of the utilities
- M2 Progress in substrate coating
- M3 Customer acceptance
- M4 Planning has begun
- M5 Permits issued for implementation

M6 Own coating line?
M7 Technology providers offer
M8 Employees trained
M9 Definition of necessary R&D projects

3. Timeline Substitution Black chromium

a. Evaluation of Cr(III) Technology
M1 Reports on the status of the utilities
M2 Definition of necessary R&D projects

b. Evaluation and development of PVD Technologies
M1 Reports on the status of the utilities
M2 Customer acceptance
M3 Planning has begun
M4 Permits issued for implementation
M5 Own coating line?
M6 Technology providers offer
M7 Employees trained
M8 Definition of necessary R&D projects

c. Evaluation and development of advanced Painting Technologies
M1 Reports on the status of the utilities
M2 Customer acceptance
M3 Planning has begun
M4 Permits issued for implementation
M5 Own coating line?
M6 Technology providers offer
M7 Employees trained
M8 Definition of necessary R&D projects

4. Timeline Hard – functional Chromium

a. Evaluation of Cr(III) Technology
M1 Reports on the status of the utilities
M2 Status of industrial implementation defined; further steps depend on it
M3 Technology is known to customers
M4 Customers Acceptance
M5 Planning has begun
M6 Permits issued for implementation
M7 Technology can be produced in series
M6 Cr(III) available for companies use
M9 Technology can be produced in broader series
M10 Can boric acid be dispensed?
M11 Series production with secure supply to children is possible
M12 About 90% of production converted
M13 Employees qualified
M14 Definition of R&D projects necessary for the implementation of Cr(III) technology

b. Evaluation other technologies
M1 Reports on the status of the utilities
M2 Status of industrial implementation defined; further steps depend on it
M3 Customer acceptance
M4 Planning has begun
M5 Permits issued for implementation

M6 Own coating line?
M7 Technology providers offer
M8 Employees trained
M9 Definition of necessary R&D projects

5. Other

a. Anodising
M1 Technology ready
M2 Substitution done (4 years expected)
M3 Certification done
M4 Definition of R&D projects necessary

b. Colouring
M1 Technology decision
M2 Substitution predictable (not assessable)
M4 Definition of R&D projects necessary

4. MONITORING OF THE IMPLEMENTATION OF THE SUBSTITUTION PLAN

The current technical evaluation needs to be validated on an ongoing basis. This will occur in conjunction with the chemical suppliers as well as the end users.

The technological development process itself is continuously evaluated and experiences shared with market companions among all the companies involved.

4.1 General VECCO platform

Based on the recommendations, hapoc and VECCO have developed a structure that enables the companies to jointly appraise the situation and work together towards further technical and scientific development. KTB will use the activities of both VECCO and hapoc.

Research and development projects will therefore be conducted together with the eiffo scientific network as and when needed. These will preferably be carried out by the VECCO companies concerned, but this is not fundamentally restricted to such companies.

An understanding of the situation at the companies will be ensured through regular monitoring of the relevant data. This data will be jointly evaluated and made available to the companies.

Joint monitoring will occur through comparative reports. The reports will be published in an annual compendium and could be made available to the authorities as field reports.

Moreover, VECCO and hapoc have developed an enhanced IT-based information platform. Companies can use this platform to find out about the state of technological development.

Their own activities can be compared against the entire VECCO spectrum.

Application of this structure enables data to be collected on a regular basis and, above all, data analysis, and thus access to a very current presentation of the findings as they relate to the current developments in terms of risk management measures.

The findings of information gathered in such a way will allow representative conditions to be presented.

4.2 Specific tools for monitoring and evaluation

The IT platform currently developed for entering and evaluating risk data has proven to be suitable (general structure is shown in Fig. 12).

The application of this structure will allow regular data collection and, above all, analysis of data and information. This makes it possible to present current developments with regard to risk management measures. The results of the information collected in this way allow representative conditions to be presented.

These serve as a basis for the preparation of the CSR chemical safety report. The CSR will be prepared for future applications in a general and generally applicable manner.

Consequently, the contents of the CSR can be prepared centrally by VECCO and hapoc and made available to companies so that they can take appropriate measures.

In the same way, the information on substitution can be collected and evaluated centrally.

The developed platform will be further developed based on the discussions shown above.

VECCO will carry out regular monitoring programmes for this purpose. Within the framework of these programmes, both the development of risk data and efforts to achieve substitution will be surveyed.

At the same time, VECCO will support the companies to implement substitution.

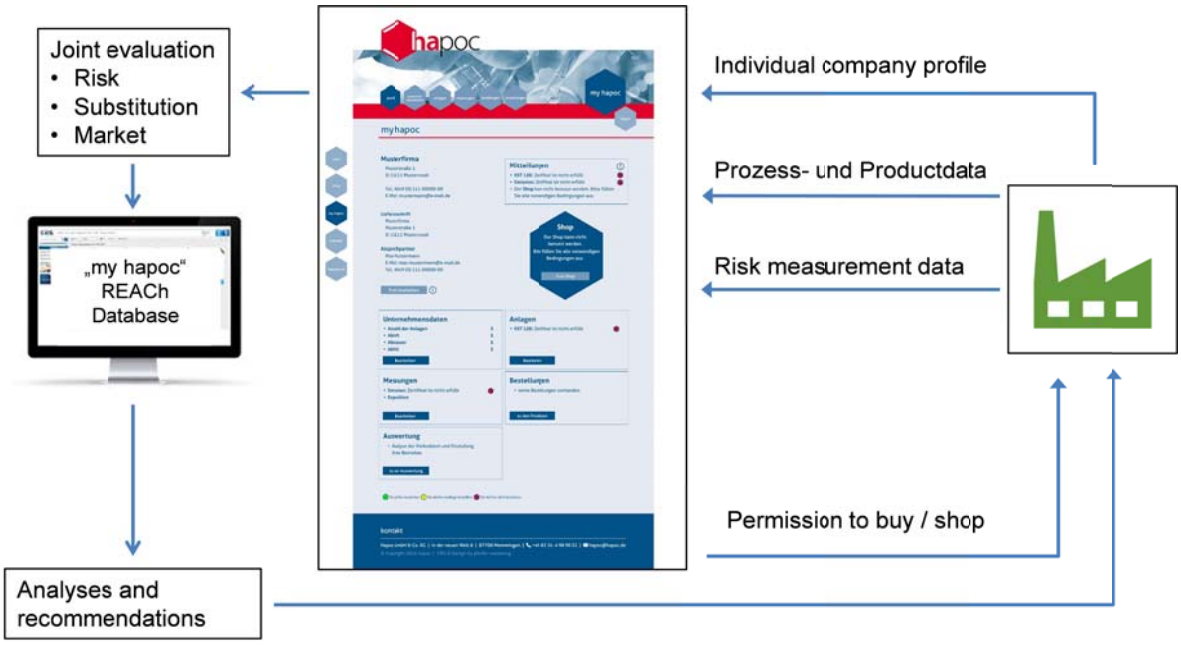


Fig. 12: Consolidated information structure VECCO/hapoc

At the same time, VECCO will support the companies in the implementation of substitution.

The existing procedure for collecting and presenting product-related information will be used for this purpose (point 1).

The spider diagrams, which have proved to be very useful, will be used to describe the detailed characteristics of the products and product groups (point 2).

This information will be made available in the database for further use by the participating companies.

1. Collection of product properties

The intended structure to describe the product characteristics will be based on the following structure:

Product group	No. articles	Turnover share	Supply chain (usually many)	Key functionalities Analysis according to spider diagram
Automotive	100	20 %	• Consumption • Furniture • Sanitary • Mechanical Engineering • Toolmaking	• Adhesion • UV resistance • Wear resistance • Hardness • Layer thickness • Corrosion Resistance • Nickel release • Appearance
Textiles	50	30 %	• Textile Industry • Furniture • Trade	• Wear resistance • Hardness • Layer thickness • Corrosion Resistance • Nickel release • Appearance

Defense Technology	20	20 %	• Weapons Technology • Projectile ammunition	• Wear resistance • Hardness • Layer thickness • Corrosion Resistance • Coefficient of Friction • Influence of the surface morphology
Sanitary	100	10 %	Sanitary	See above
Furniture/Shop building	100	30 %	Consumer Trade	See above

Table 42: Example analysis of a product (utilisation) for use in the database

2. Evaluation of key functionalities by spider diagrams

Schlüsselanwendung: key application	Dekorativ-funktional	Functional decorative chromium plating		Produkt:	Steering wheel
Alternative:	Cr(III)			Lieferkette:	Automobil
key functionalities:	11				
Sprache Netzdiagramm:	deutsch				
Funktion deutsch	englisch	Chromat (Bezug = 100)	Alternative	Bedeutung deutsch	englisch
Korrosionsbeständigkeit	corrosion resistance	100	100	sehr hoch	necessary
Chemikalienbeständigkeit	chemical resistance	100	80	sehr hoch	necessary
Verschleiß-/Abriebfestigkeit	wear/abrasion resistance	100	90	sehr hoch	necessary
Verhinderung von Nickelauswaschung	prevention of nickel leaching	100	50	sehr hoch	necessary
Haftung	adhesion	100	80	mittel	mean
Härte	hardness	100	40	mittel	mean
Sonnenlicht-/UV-Beständigkeit	sunlight/UV resistance	100	80	sehr hoch	necessary
Temperatur-/Wärmefestigkeit	temperature/heat resistance	100	80	mittel	mean
elektrische Leitfähigkeit	electrical conductivity	100	100	niedrig	low
Reflexionsverhalten/Absorptionsfähigkeit	reflection behaviour/absorption capability	100	90	mittel	mean
Ästhetik	aesthetics	100	80	sehr hoch	necessary

Fig. 13: Example application: steering wheel, decorative-functional, 11 key functions

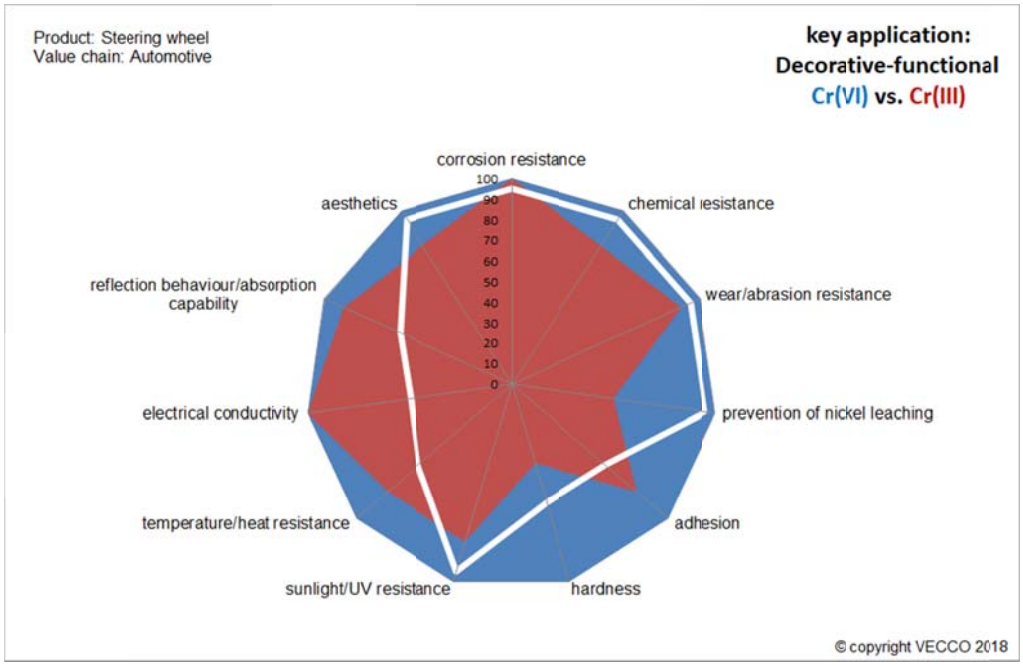


Fig. 14: Example evaluation of possible alternatives: steering wheel, decorative-functional, 11 key functionalities (The white circle indicates the relevance of the functionality)

3. Extended structure to be used

Based on the recommendations, the structure developed by hapoc and VECCO allows a joint assessment of the situation of the companies and a joint further technical and scientific development.

In addition to the well-known cooperation between hapoc, VECCO and eupoc, cooperation agreements were concluded with the scientific network eiffo eG and the journalist network WoTech.

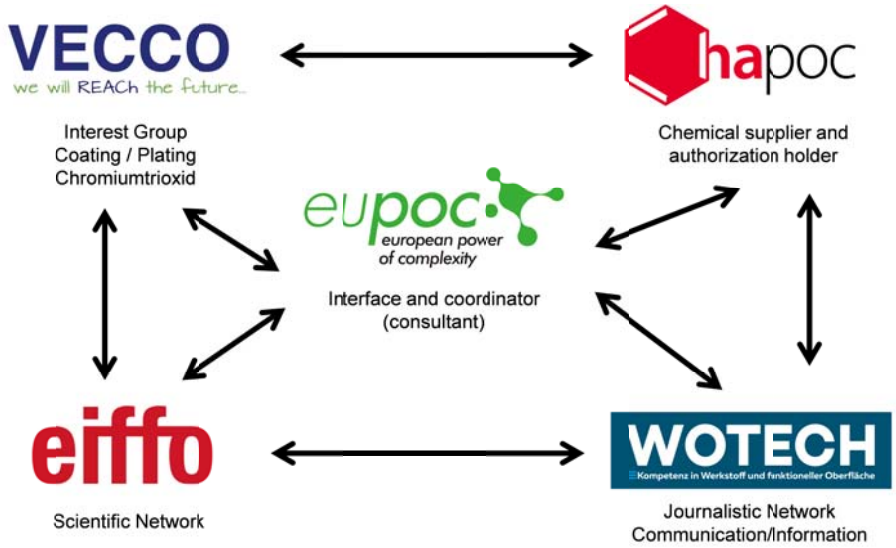


Fig. 15: Working concept of VECCO network

The companies involved themselves have but few possibilities to carry out the required technical developments. Even information about possibilities is only possible to a limited extent.

Therefore, research and development projects will be carried out jointly with the scientific network eiffo. These are preferably carried out by the VECCO companies concerned, but are not limited to them in principle.

Knowledge of the situation of the companies is provided by regular monitoring of the relevant data. This data is evaluated jointly and made available to the companies.

Together with the sector journal WOTECH, experience reports on possible substitutions are compiled and published.

The reports are published in an annual compendium and also made available to the authorities.

4. Spreading and Follow-up activities

The further distribution and provision of the information will take place by means of

- Workshops
- Webinars
- Regular publications
- Collection of R&D results
- Identification of relevant R&D topics
- Setup of relevant R&D projects

5. Evaluation

The results are discussed and compared at joint events and further field tests are organised.

5. CONCLUSIONS

The present application was submitted by the hapoc representing the downstream of the VECCO association. As a consequence, this substitution plan described the possibilities and actions of these companies.

The focus is on evaluating and creating opportunities for the companies to realise substitution and at the same time to continue to exist and thus survive on the market. It is not possible to develop a uniform substitution plan for all applications, utilisations and companies. The specific concerns of the companies and applications concerned must be given priority.

The objective of the substitution plan presented here is therefore to enable the companies involved to develop plans for the replacement of Cr(VI) technology together with their customers. For this purpose, criteria and implementation options have been developed which the companies can evaluate with the support of VECCO / hapoc to implement independently.

The application submitted by hapoc covers the following uses:

1. functional chrome plating - hard chrome plating
2. functional chrome plating with decorative character
   a. Bright chrome plating
   b. Black chrome plating
3. electropolishing
4. decoating
5. plastic etching
6. anodising (specific companies)
7. passivation (thin), incl. stainless steel colouring (specific companies)

In the meantime, the decoating and electropolishing applications are no longer used separately by the companies. The "decoating" application is increasingly integrated into the coating production process. For this reason, it was not generally considered in the present study.

The following key applications remain

1. functional chrome plating - hard chrome plating
2. functional chrome plating with decorative character (Bright chrome plating)
3. Black chrome plating

Special applications like anodising and stainless steel colouring are used by a very limited number of companies. Their special conditions have been taken into account. The criteria for the decorative-functional application were used as a basis and the other applications were evaluated comparatively using these criteria.

The companies will focus on the substitution of technologies that can be realised using the existing production processes. As the customers require chromium metal, the use of Cr(III) technologies is seen and implemented as the most promising substitution.

In special cases, other technologies like PVD can additionally be deployed, usually in cooperation with the customers. However, this will not enable general substitution.

It is imperative to involve customers along the value chain. Only they can provide meaningful alternatives in basic materials and design for their specific product, combination of partial products or service. The main challenge for successful substitution is therefore to include the representatives of the value chain. Only if customers and end users are included can the substitution of Cr(VI) chemicals be successful.

The main focus must therefore be on cooperation between all the companies involved, while at the same time giving the companies as much flexibility as possible to implement substitution under their specific conditions.

For practical implementation, it is necessary that the customer is willing to give an acceptance guarantee. The companies are of the opinion that the financial expenditure is then critical, but feasible. Support from public institutions would intensify the process.

As soon as the customers have made these commitments, planning for the substitution can begin. It is assumed that a changeover can then take place within 2-3 years.

Nevertheless, some special applications will require a longer period of time. This will be supported by the implementation of R&D projects.

This is also because the companies are already working continuously on the further development of their technology with the support of VECCO. The companies have made various attempts with the CrIII coating system, both in-house and in cooperation with chemical suppliers for example. These efforts require an intensified support of their customers. It is necessary to involve them in the concrete discussions, which has not been done sufficiently so far

Where necessary and possible, field tests have been and will be jointly conducted by the companies and their customers. This will also occur in conjunction with market companions from the relevant industries as well as other branches of industry.

This has been happening for many years through the VECCO platform.

In terms of spare parts and repairs, the expectation is that demand will continually recede. This therefore makes it necessary to maintain a low level of Cr(VI)-based process capacity.

6. REFERENCES

1. T. Öberg, Commentary on the Löfstedt substitution paper, Journal of Risk Research, 17.5 (2014), 565
2. R. Löfstedt, “The substitution principle in chemical regulation: a constructive critique”, Journal of Risk Research, 17.5 (2014), 543
3. O. Renn, Journal of Risk Research 17.5 (2014), 597
4. J. Girling, Commentary on the Löfstedt substitution paper, Journal of Risk Research, 17.5 (2014), 593
5. MITTEILUNG DER KOMMISSION AN DAS EUROPÄISCHE PARLAMENT, DEN RAT UND DEN EUROPÄISCHEN WIRTSCHAFTS- UND SOZIALAUSSCHUSS - Gesamtbericht der Kommission über die Anwendung der REACH-Verordnung und die Überprüfung bestimmter Elemente - Schlussfolgerungen und Maßnahmen, EU Kommission 2018
6. Informations- und Dialogveranstaltung „Perspektiven der Substitution für Cr(VI) – Funktionieren die Alternativen und sind sie bezahlbar?“, BAuA, Dortmund, 14.01.2019
7. “Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating”, BAuA - Federal Institute for Occupational Safety and Health, 1st edition 2020 Dortmund/Berlin/Dresden
8. Impacts of REACH Authorisation - Final Report
9. EUROPEAN COMMISSION, DG Internal Market, Industry, Entrepreneurship and SMEs, Directorate D — Consumer, Environmental and Health Technologies, November 2017
10. Approaches for Accelerating Substitution under REACH and Beyond: Strategic Options Assessment;
11. J. Tickner, M. Jacobs, G. Howard, University of Massachusetts Lowell, Lowell Centre for Sustainable Production, 31 July 2017
12. Oxford Basil Blackwell, 1955.
13. Technology substitution and innovation adoption: The cases of imaging and mobile communication markets, L. Miranda, C. Lima (Technological Forecasting and Social change, Volume 80, issue 6, July 2013 pp. 1179-1193). http://www.sciencedirect.com/science/article/pii/S0040162512002880
14. A well-known one is the Bass Model; *Bass, Frank M. (2004). "Comments on "A New Product Growth for Model Consumer Durables": The Bass Model"*
15. Dynamics of Social Factors in Technological Substitutions , Brice Dattée, Henry Birdseye Weil – MIT Sloan School of management Working Paper # 4599-05
16. /https://www.ptj.de/lw_resource/datapool/systemfiles/cbox/2373/live/lw_file/definition_des_technologischen_reifegrades.pdf bzw. https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
17. Beizen von Kunststoff - https://www.wotech-technical-media.de/womag/ausgabe/2015/12/26_zvo_berlin_12j2015_3/26_zvo_berlin_12j2015_3.php
18. https://www.wotech-technical-media.de/womag/ausgabe/2018/11/26_hofinger_kunststoff_11j2018/26_hofinger_kunststoff_11j2018.php
19. Description of Bionex - https://www.biconex.de/

Annex – Justifications for ConfidentialiTy CLAIMS

[Insert text and table here]

Blanked out item reference	***Page number***	***Justification for blanking***
Table 1	*14 - 16*	*List of members is not to public*
Fig. 3	*61*	*Distribution of turnover is internal data*

APPENDIXES

6.1 Appendix 1 Consultations

none

6.2 Additional appendices

1. Concept to be used for future application for authorisation for Chromium-trioxide, presented to ECHA 19.3.2019
2. VECCOs Initiative for an innovation network in the surface technology industry, Presented to ECHA 12.05.2020
3. Timetable Excel Format