ANALYSIS OF ALTERNATIVES (AOA)

AND

SOCIO-ECONOMIC ANALYSIS (SEA)

Public version

Legal name of applicant: *Borealis Plastomers BV*

Submitted by: *Borealis Plastomers BV*

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Substance: *Sodium dichromate;*

CAS 10588-01-9; CAS 7789-12-0

EC no: 234-190-3

Use title:

(1) The use of Sodium dichromate as in-situ corrosion inhibitor in a closed water/ammonia absorption cooling system

Use number: *Use 1*

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IMPORTANT NOTE FOR THE READER OF THIS AOA/SEA REPORT

- Borealis Plastomers B.V. is referred to as Borealis.
- The Socio-Economic Analysis uses information from the Chemical Safety Report (CSR). The latter is compiled based on the hazard information, Excess Lifetime Risks determined by RAC (published by ECHA on 4 Dec 2013), reprotoxicity related DNELs communicated via the ECHA Secretariat and a Company specific exposure assessment.
- Article 62.4(d) of REACH stipulates that the authorisation dossier shall contain a Chemical Safety Report (CSR) covering the risks to human health and/or the environment from the use of the substance arising from the intrinsic properties specified in Annex XIV, i.e Carcinogenic Cat. 1b, Mutagenic Cat. 1b and Reprotoxic Cat. 1b. Therefore the CSR focusses on the Carcinogenicity, Mutagenicity and Reprotoxicity endpoints, whereas in the Analysis of Alternatives (AoA) other endpoints are also considered for the comparison of potential alternatives.

Use of decimal marks in this report:

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

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

If this report is read from a printed document, there are a number of pictures in this report which are best viewed in colour.

LIST OF ABBREVIATIONS

AfA	Application for Authorisation
AoA	Analysis of Alternatives
CBA	Cost-Benefit Analysis
CBI	Confidential Business Information
Cr(VI)	Hexavalent Chromium
Cr(III)	Trivalent Chromium
CSR	Chemical Safety Report
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area
EFTA	European Free Trade Area
ELR	Excess Lifetime Risk
ES	Exposure Scenarios
EVA	Ethyl vinyl acetate
EU	European Union
EUROSTAT	Statistical Office of the European Communities
FTE	Full Time working Equivalent
GDP	Gross Domestic Product
HDPE	High Density Polyethylene
IARC	International Agency for Research on Cancer
IOM	Institute of Occupational Medicine
ISCED	International Standard Classification of Education
LDPE	low-density polyethylene
LLDPE	Linear low-density polyethylene
kt/year	Kilo (1.000) tonnes per year
MRO	Maintenance, Repair and Overhaul
MVE	Man via the Environment
$Na_2C_r2O_7$	Sodium dichromate
NewExt	New Elements for the Assessment of External Costs from Energy Technologies
NPV	Net Present Value
NUS	Non-Use Scenario
OECD	Organisation for Economic Cooperation and Development
OHS	Occupational Health and Safety
PE	Polyethylene

PEC	Predicted Environmental Concentration
PP	Polypropylene
PVC	Polyvinylchloride
RAC	Risk Assessment Committee
ROI	Return on Investment
SEA	Socio-Economic Analysis
SEAC	Socio-Economic Analysis Committee
SMEs	Small and Medium Enterprises
SVHC	Substance of Very High Concern
TPO	Thermoplastic Polyolefin
VLDPE	very low-density polyethylene
VOLY	Value of Life Year lost
VSL	Value of Statistical Life
WTP	Willingness to Pay

DECLARATION

We, Borealis claim the information blanked out in the "public version" of the Analysis of Alternatives and Socio-economic analysis and which is specified in Appendix F confidential. We hereby declare that, to the best of our knowledge as of today (17^{th} of March 2016) the information is not publicly available, and in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to the information claimed confidential without our consent or that of the third party whose commercial interests are at stake.

S. CALUWE

Stefan Caluwe
Borealis Plastomers B.V.
Geleen

Date, Place: Geleen, 15/03/2016

1. SUMMARY OF AOA AND SEA

Key findings

The purpose of this box is provide a high level summary of the key findings of this Application for Authorisition (AfA - made up of the Chemical Safety Report – CSR, Analysis of Alternatives – AoA, and Socio Economic Analysis – SEA):
 	
1. The risks are minimised:
  a. There is no consumer exposure to sodium dichromate from products made;
  b. There are negligible risks to workers;
    i. Lung cancer risks are valued at less than two euros (PV over 20 years)
  c. No exposure to the environment; and
  d. No exposure to man via the environment; and
  e. The typical volume used (60kg/3yrs) is minimal and has been minimised by optimising the production process.
2. There are no suitable alternatives to Borealis Plastomers BV (the applicant)
3. The socioeconomic benefits of continued use estimated at ~€[redacted] million[1] (PV over 20 years).
4. The evidence demonstrates that the benefits of continued use far exceed the risks to human health and the environment.
5. The evidence also demonstrates the case for a review period of 18 years.
 	
The supporting evidence to justify these statements are provided within this AfA – some within the CSR in relation to minisation of risks and the rest contained within this combined AoA and SEA report. Whilst the AfA may go in detail on certain aspects in order to provide supporting evidence to the ECHA committees and the European Commission, the results are clear and justify this application being considered an **"exceptional case"** warranting a review period longer than 12 years which is currently defined as a "long" review period, in part **because the cost to human health and environment is as close as possible (feasible) to zero.**

1.1. Background

The applicant for this AfA is Borealis Plastomers BV based in Geleen in the Netherlands. At the Geleen site, two polyethylene (PE) products are made:

1. Queo™ - a Linear Low Density Polyethylene (LLDPE); and
2. Stamylex ™ - a very low-density polyethylene (VLDPE) or a high-density polyethylene (HDPE).

Both Queo and Stamylex are made in a continuous solution polymerisation process operated 24 hours a day, seven days a week. At this site, there are two production lines (called "Line 1" and

"Line 2" in this AfA) which can produce both types of polyethylene products. However, overall the main product produced at Geleen is Queo (a highly specialised premium product) whilst Stamylex (although also a specialist product) is produced in smaller quantities in part to utilise the production capacity of the Geleen plant but also to fulfil a niche (subset of the) market whereby customers demand Stamylex in smaller batches.

Within the EEA, aside from Borealis Plastomers B.V. there is only one other EU manufacturer of an equivalent LLDPE (to Queo) called [redacted] provides [redacted] of the EU market and Borealis [redacted].[2] There are more suppliers of similar or adequately performing PE to Stamylex (either a high density (HDPE) or Very Low density (VLDPE) polyethylene) both within and outside of the EEA.

Further details are provided in this report but essentially the Geleen site has two ammonia/water absorption coolers installed on one of the two production lines (referred to as "Line 1" in this AfA) used to make both Queo and Stamylex. These ammonia/water absorption coolers use sodium dichromate (within a closed system) as a corrosion inhibitor. Sodium dichromate is used as an in-situ corrosion inhibitor which helps to extend the lifetime of the carbon steel constructed closed water/ammonia absorption cooling system. Without the sodium dichromate, the carbon steel would corrode rapidly in contact with a water/ammonia mixture especially at elevated temperatures.

The second polymerisation line (referred to as "Line 2" in this AfA) differs by the way that the inlet stream to the reactor is cooled. In this parallel production installation, Borealis utilizes a compressor based system to achieve the required low inlet temperature. Sodium dichromate is not used for "Line 2" and any resulting production would be unaffected by the outcome of this authorisation application.

The plant has successfully been using a small amount of sodium dichromate (60 kg every 3 years) as an in-situ corrosion inhibitor since 1971 with no evidence of any corrosion. However, sodium dichromate ($Na_2Cr_2O_7$; EC no: 234-190-3) is according to Article 57(a) of Regulation (EC) N° 1907/2006 a substance of very high concern (SVHC) due its Carcinogenic Cat. 1B, Mutagenic Cat. 1B and Reprotoxic Cat. 1B properties. Sodium dichromate was included in the list of substances subject to authorisation (Annex XIV) with a sunset date of 21/9/2017. This means Borealis requires authorisation for continued use after this date.

Because of the low volume that Borealis uses (and is forecasted to continue to use around the same amount) this AfA meets all the criteria as proposed by the EU Commission for the application for authorisation for low volume uses (i.e. volume < 100 kg per year). This should be taken into consideration when ECHA and the EC makes its decision but since the Implementation Regulation for authorisation applications for uses in low quantities has not come into force at the time of submission all elements with regard to CSR AoA and SEA of a standard dossier have been handled in full in this application for authorisation. Moreover, this application for authorisation provides all elements required and a detailed justification for a very long review period.

We also note that the applicant had requested an exemption for this use on the basis that there is negligible exposure. The answer to the request is still pending. Hence, the applicant has decided to submit this "safety-net" application for authorisation, in which it is demonstrated, on the basis of measurement data, that the exposure to workers, environment and man via the environment is indeed negligible.

1.2. Applied for use scenario

Under the applied for use scenario, Borealis would continue to use sodium dichromate as a corrosion inhibitor in their water/ammonia absorption cooling installation ("Line 1") at their Geleen site for the following reasons:

[redacted][3]

2. Sodium dichromate has a proven track record at the Borealis site as being an excellent corrosion inhibitor meaning that that Line 1 can continue to operate for the foreseeable future (i.e. next 20 years) with minimal periodic investment (which is required regardless of the technology used). To date there is no evidence of any corrosion and there is no evidence of an alternative corrosion inhibitor being as effective as sodium dichromate, let alone one that has a long and proven track record.
3. The volume of Sodium dichromate needed for this use is very small. The historical use is only about 60 kg over three years.
4. Sodium dichromate is used in a closed system, and as shown in the CSR, even under (unrealistic) worse case assumptions there are negligible risks to workers, no consumer exposure, and no exposure to the environment (or man via the environment). A summary of the CSR can be found in in Section 2.8.
5. There are no suitable alternatives for Borealis for the replacement of the Annex XIV substance function (which is demonstrated in Section 3).

1.3. Analysis of alternatives (AoA)

The AoA (as shown in Section 3 of this report) sets out the key functional requirements of sodium dichromate specifically for this use as an in situ corrosion inhibitor in a closed water/ammonia absorption cooling system. Ten alternatives were considered ranging from; a drop in alternative, possible technology changes, and a different end-product to LLDPE elastomers. None of the alternatives was deemed 'suitable' but three were assessed further in more detail:

- Installing a compressor based cooling system;
- Partial replacement of corrosive sensitive equipment; and
- Alternative, drop-in corrosion inhibitor.

Replacing the current absorption cooling system with a compressor based cooling system is technically feasible, and would result in a lower overall risk, it is not deemed economically feasible, and nor would be available by the sunset date. Whilst there is some energy and CO_2 savings from using compressor based cooling system, there is a negative net present value (NPV) of -€4.9 million (over 20 years using a 10% discount rate). This is further compounded by the fact that there will be a loss of profits ([redacted][4], PV, over 20 years using a 10% discount rate) within the EEA until the compressor technology would be fully operational and market share (optimistically) regained.

Both the selection of an alternative corrosion inhibitor and the use of alternative construction material entail a risk of corrosion, loss of containment and interruption of production. As such, these alternatives are both not technically feasible and provide uncertain risk reduction potential. The partial replacement of corrosive sensitive equipment has an even higher cost to Borealis, does not represent a long term solution, and does not have any operating cost savings. For this reason it is even worse (economically and technically). The identification and testing of new corrosion-resistant materials and alternative inhibitors is subject to considerable uncertainty, in terms of both success in identifying suitable candidates for adoption as well as the ultimate performance of those candidates when implemented. The business risks associated with these options – particularly the potential for a complete failure of the installation – are too great to be considered further by Borealis.

1.4. Non-use scenario

After the sunset date the only option available to Borealis would be to shut down Line 1 completely as it is dependent on the use of sodium dichromate as a corrosion inhibitor. In order to minimise the long term loss of profits to Borealis from reduced production capacity, Borealis's only option is to replace Line 1 with a compressor based cooling system. Borealis would do this despite there being a negative NPV as using a compressor is the only technically feasible alternative and it thus provides Borealis with the only realistic certainty of continued production similar to under the applied for use scenario. As is set out in Section 3.7 it is estimated that it will take at 3-4 years from the start of the engineering before a compressor system can be operational.

1.5. Comparison of costs and benefits

The analysis finds that the estimated benefits of continuing use outweigh the associated risk to human health. The benefits of this continued use of sodium dichromate are the costs which can be avoided by Borealis by not adopting the compressor based technology and the avoided lost profit during the temporary loss of capacity until the compressor based technology is operational. The monetised benefits are estimated to be approximately ~€[redacted] million (Present Value – PV over 20 years using a 4% discount rate):

- Avoided capital cost less the higher energy and CO_2 costs (compared to use of compressor technology) estimated at ~€1.4 million; and
- Avoided lost profit to Borealis of ~€[redacted] million.[5]

Based on the screening of possible health and environmental impacts, the only health impact of relevance (although not deemed significant) is the excess lung cancer risk to workers from inhalation exposure to sodium dichromate from continued use. However this cost is estimated in total to be €1.5 (PV, realistic estimate over 20 years) and therefore it is clear when comparing the negligible (if any net) health costs of continued use to the economic and social benefits of continued use that society would be better off if authorisation were granted. Any uncertainties or key variables used in the analysis are not sensitive enough to affect the conclusion that the benefits of authorisation outweigh the risks of continued use.

1.6. Conclusion and requested review period

Based on the evidence presented in this application, Borealis is seeking a review period of 18 years as it meets what the ECHA (2013)[i] guidance on setting a review period refers to as an 'exceptional' case.

Borealis uses sodium dichromate in a closed system and as the CSR clearly demonstrates even under (unrealistic) worse case assumptions that:

- There is no consumer exposure;
- There are negligible risks to workers (cancer risks valued at ~€1.5 PV over 20 years which are effectively as close to zero as feasible);
- No exposure to the environment;
- No exposure to man via the environment; and
- Use of the substance is very low (typically 60kg/3yrs).

With minimal periodic investment (which is required regardless of the technology used), Line 1 can continue to operate well beyond the next 20 years. Borealis therefore have no long term plans to change Line 1 because:

1. The market is expected to grow over the next 10 years (forecasting beyond this is very difficult) and this would require the full capacity available of Borealis Line 1 and 2;
2. There are no suitable alternatives for Borealis for the replacement of the Annex XIV substance function. Borealis would continue to research new technologies but currently there are no new/emerging technologies (e.g. cooling equipment, cooling technologies or superior products) that Borealis are aware of that will be available within the next 18 years.
3. Past research has not lead to a suitable alternative. Any further research in-house would cost €[redacted][6] , which is not proportionate to the minimal impact of €1.5 to human health and environment.
4. There is a long and proven track record of producing Stamylex and Queo using sodium dichromate as an in-situ corrosion inhibitor in a closed water/ammonia absorption cooling system. To date there is no evidence of any corrosion, which is vital given Borsig 1 installation has no allowance for corrosion, and there is no evidence any alternative corrosion inhibitor being as effective as sodium dichromate, let alone one that has a long and proven track record.

[i] (ECHA 2013) – "Setting the review period when RAC and SEAC give opinions on an application for authorisation". Available at: https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf

5. Borealis has invested significant time and resources in ensuring worker safety. As the risks are negligible, it does not make financial sense to invest significant amounts of money on any known (unsuitable) alternatives.
6. As demonstrated in the non-use scenario, it is not in societies best interests for Borealis to replace Line 1 with a compressor cooling system as even after 20 years any energy and CO_2 savings do not outweigh the initial investment costs. This is further compounded by the fact that there will be a loss of profits within the EEA until the compressor technology would be operational. Relative to the risks of continued use (€1.5 PV over 20 years) it is clear that such an investment is not justified as there could be more productive uses of that investment in the future (i.e. projects that return a positive NPV).

Taking into consideration all of the information presented in the application, the evidence clearly justifies this application for authorisation being considered an exceptional case with a review period of 18 years.

2. AIM AND SCOPE OF AOA AND SEA

2.1. Aim

Sodium dichromate ($Na_2Cr_2O_7$; EC no: 234-190-3) is according to Article 57(a) of Regulation (EC) N° 1907/2006 a substance of very high concern (SVHC) due to its Carcinogenic Cat. 1B, Mutagenic Cat. 1B and Reprotoxic Cat. 1B properties. On December 4, 2013 ECHA published the document "Application for Authorisation: Establishing a reference dose response relationship for carcinogenicity of hexavalent chromium"[ii], which constitutes the opinion of the Risk Assessment Committee (RAC) that hexavalent chromium is considered to be a non-threshold carcinogen. As a result, demonstrating adequate control for that endpoint is not possible and the SEA route is applicable. With regard to the reprotoxicity endpoint however, a threshold was defined (not yet published, but provided by ECHA Secretariat in view of the timing of this AfA) and the adequate control route is applicable for that endpoint.

Sodium dichromate has been included in the list of substances subject to authorisation (Annex XIV) with a sunset date of 21/9/2017. Authorisation is therefore required for continued use after this date.

If, based on the justifications provided by the applicant (Borealis Plastomers BV), the authorisation is granted then Borealis will continue ("applied for use scenario"):

> *The use of sodium dichromate as in-situ corrosion inhibitor in a closed water/ammonia absorption cooling system*

The aim of this application is to demonstrate:

- **Emissions of sodium dichromate have been minimised** - This is shown in the chemical safety report (CSR).
- **There are no suitable alternatives** by the sunset date to sodium dichromate for the applicant for this specific use - This is shown within this report and in particular in Section 3.
- That the **benefits to society from continued use outweigh the risks to human health and the environment** - This is shown within this report and in particular Section 6.

2.2. The applicant and the production site affected

Borealis is a multinational company with headquarters in Vienna (Austria). Borealis currently employs around 6,500 people across 120 countries, and in 2014, it generated sales revenue of €8.3 billion[iii].

[ii] ECHA: http://echa.europa.eu/documents/10162/13579/rac_carcinogenicity_dose_response_crvi_en.pdf

[iii] Available at: http://www.borealisgroup.com/en/company/about-borealis/about-borealis/

Borealis operates across three main fields:

1. Polyolefins;
2. Base chemicals; and
3. Fertilisers.

The applicant for this Application for Authorisation (AfA) is Borealis Plastomers BV based in Geleen in the Netherlands. At the Geleen site, two polyethylene products are made:

1. Queo™ - a Linear Low Density PolyEthylene (LLDPE); and
2. Stamylex ™ - a very low-density polyethylene (VLDPE) or a high-density polyethylene (HDPE).

The manufacturing unit was originally built by a company called DSM in 1971-1973 and used the Ziegler-Natta type catalyst process to make polyethylene (and this process is still used to make Stamylex). Today the unit is owned and operated by Borealis. The production site was modified to enable the use of a different catalyst when required. Unlike with Stamylex, for the production of the Queo product, a metallocene type catalyst (introduced in 1997) is used instead of the original Ziegler-Natta type catalyst.

Both Queo and Stamylex are made in a continuous solution polymerisation process operated 24 hours a day, seven days a week. At this site, there are two production lines (called “Line 1” and “Line 2” in this AfA) which can produce both types of polyethylene products. However, overall the main product produced at Geleen is Queo (a highly specialised premium product) whilst Stamylex (although also a specialised product) is produced in smaller quantities in part to utilise the production capacity of the Geleen plant but also to fulfil a niche (subset of the) market whereby customers demand Stamylex in smaller batches. Further details of about polyethylene in general and about the two Borealis products are presented later in this chapter. But before this, it is important to briefly explain why sodium dichromate is being used as part of the production of these two types of polyethylene.

The polymerisation reaction to make these polyethylene products is exothermic (i.e. it generates heat) but the reactor is adiabatic meaning that there is not enough time to remove heat from the reactor because of the high viscosity of the reaction mixture. The maximum allowable temperature is 200°C in the reactor as defined by polymerisation chemistry.

The only way to manage the heat of the reactor without shutting down production is by lowering the inlet temperature. To do this the solvent monomer mixture going into the reactor needs to be cooled.

In order to cool the solvent monomer mixture the Geleen site has two ammonia/water absorption coolers installed on one of the two production lines. These coolers lower the temperature of the feed stream going into the reactor. The two cooling units are not the same in size but have an overall cooling capacity of [redacted] to reduce the temperature inlet (monomer and solvent) from ambient temperature to [redacted].[7] An overview of the production process is shown below in Figure 1 with more details in Section 3.1.

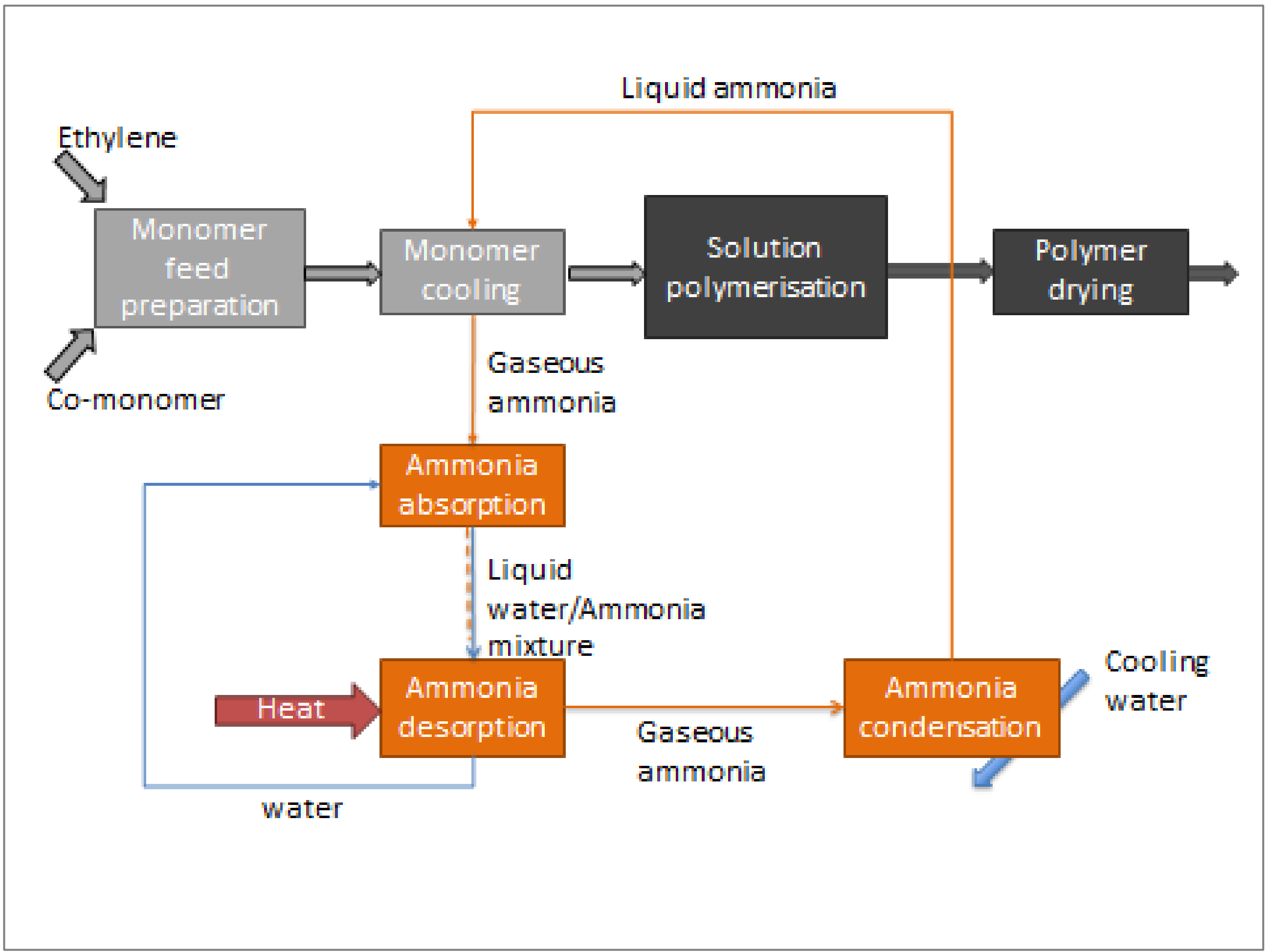

Figure 1 Overview of the production process at Geleen

As indicated above, lowering the feed stream has an important impact on improving the production capacity of these two polyethylene products. Without the cooling of the feed stream to the reactor, the capacity of the polymerisation reactor would be reduced by approximately [redacted].[8] However even more importantly, without the cooling of the feed stream it will not be possible to meet the specifications of these two polyethylene products coming out of these reactors. This is explained in Section 3. As a consequence Borealis will not be able to produce, and therefore sell, these products without feed stream cooling. Both aspects clearly indicate the crucial importance of the feed stream coolers. Without a feed stream cooling, a polymerisation reactor will not be able to produce any product within the current specifications.

Sodium dichromate is only used (within a closed system) on “Line 1” in the ammonia/water absorption cooling unit (see Figure 2) as a corrosion inhibitor. Sodium dichromate is used as an in-situ corrosion inhibitor which helps to extend the lifetime of the carbon steel constructed closed water/ammonia absorption cooling system. Without the sodium dichromate, the carbon steel would corrode rapidly in contact with a water/ammonia mixture especially at elevated temperatures.

Line 1 is dependent on the use of sodium dichromate as a corrosion inhibitor. Line 1 supports [redacted] of total production. Within Line 1 there are two installations referred to as "Borsig 1" and "Borsig 2". Borsig 1 is the larger (and older) of the two installations (accounting for [redacted] of Line 1 cooling capacity) and was not designed with any allowance for corrosion within the system.[9]

The "Borsig 2" installation which only represents [redacted] of the cooling capacity of Line 1 has a small tolerance for some corrosion within the system. [10]

The second polymerisation line (referred to as "Line 2" in this AfA) supports [redacted][11] of total production and differs by the way that the inlet stream to the reactor is cooled. In this parallel production installation, Borealis utilizes a compressor based system to achieve the required low inlet temperature. Sodium dichromate is not used for "Line 2" and any resulting production would be unaffected by the outcome of this authorisation application.

[redacted]

Figure 2. Aerial view of the ammonia/water absorption cooling unit [12]

The total production capacity in Geleen for making polyethylene is [redacted], however, the capacity of the installation, relevant for this AfA, using ammonia/water absorption coolers is [redacted]. The remainder ([redacted]) is produced using the installation with compressor cooling.[13]

2.3. Supply chain

Figure 3 provides an overview of the supply chain, illustrating which production line sodium dichromate is used in, the resulting products made by Borealis at the Geleen site (Queo and Stamylex), and the end-use applications of these products.

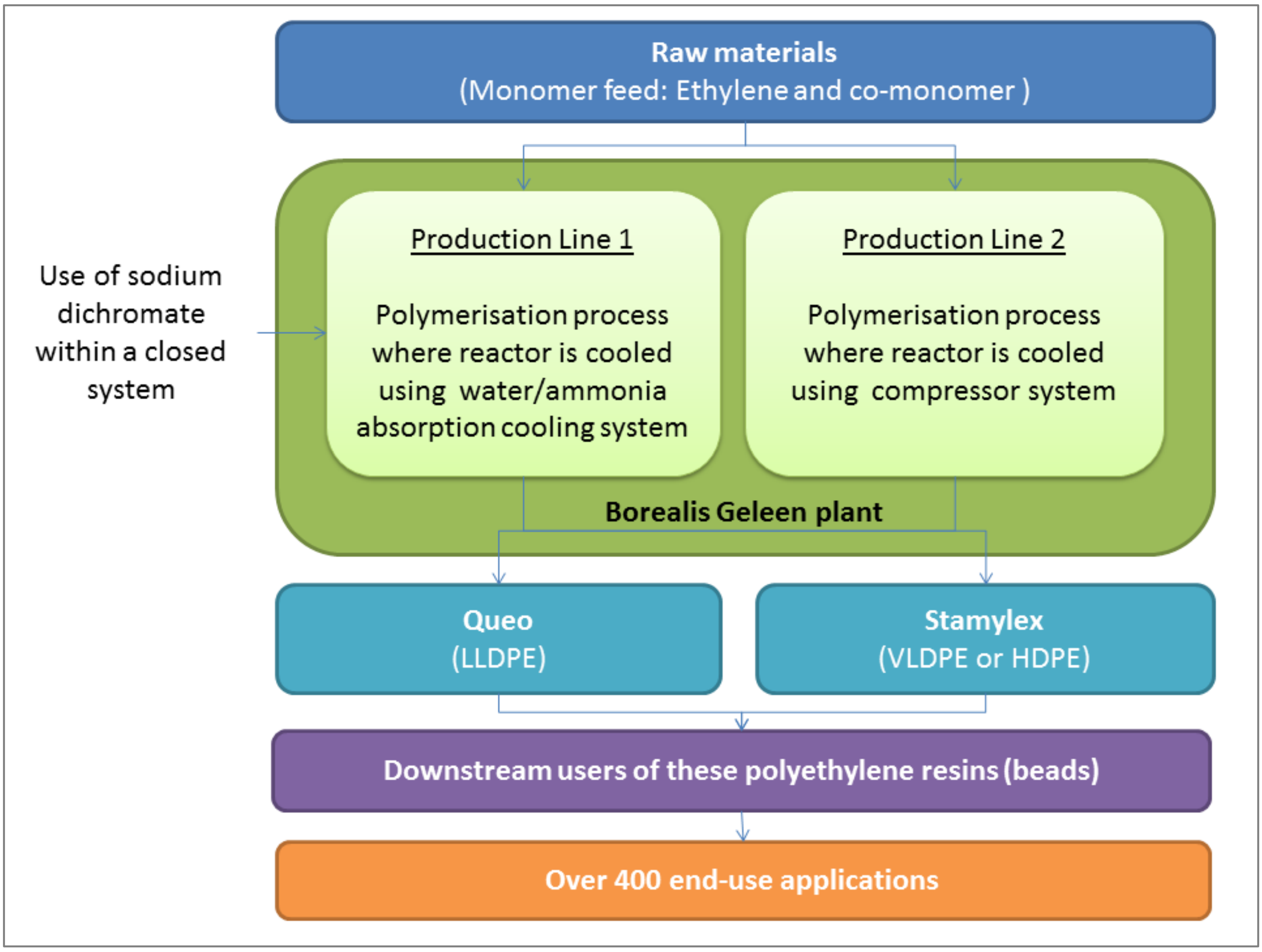

Figure 3 Supply chain overview

2.4. What is polyethylene?

Polyethylene (PE) is a polymerised ethylene, available in high, medium, low-density and linear low-density forms, which is chemically resistant and durable. Polyethylene can be moulded, extruded, and cast into many various shapes. It is a hard, stiff, strong, and dimensionally stable material that absorbs very little water, has gas barrier properties, and chemical resistance against acids, greases, and oils. It can be transparent and colourless, with thicker sections usually opaque and off-white. Polyethylene also can withstand a wide temperature range and is resistant against ultra violet radiation. According to Plastics Europe, “Polyethylene is the most abundant type of polymer produced globally, totalling over 90 million metric tonnes per year" (Plastics Europe, 2013[iv]), and has a wide range of applications (not exhaustive list):

- Packaging films;
- Laminations;
- Flexible injection products;
- Blow moulded products;
- Rubbish/lawn-leaf bags;
- Housewares;
- Bottles;
- Profiles;
- Coffee can lids;
- Dairy packaging;
- Large parts such as outdoor gym sets;
- Tanks;
- PE80 pressure pipes;
- Wire and cables;
- Anti-corrosion coating (ACC);
- Crates; and boxes;
- Bottles (for food products, detergents, cosmetics);
- Food containers;
- Petrol tanks;
- Industrial wrapping and film,
- Cling film;
- Carrier bags;
- Agricultural film;
- Milk carton coatings;
- Electrical cable coatings;
- Heavy duty industrial bags;
- Stretch film;
- Industrial packaging film;
- Thin-walled containers;
- Heavy-duty, medium- and small bags;
- Low profile additive for thermosets;/composites;
- Pultrusion processing aids;
- Dusting agent for tacky polymer surfaces;
- Sintering agent/pore former;
- Binding agent for particulates;
- Additive for coatings and adhesives; and
- Additive carrier for chemicals and pigments.

[iv] PlasticsEurope (2013). Plastics Portal; Polyethylene.

According to PlasticsEurope[v] during the production process the polyethylene can be made more or less "dense" depending on the requirements of the end-use application. PlasticsEurope estimate that around 90% of applications (as listed above) are made with one of the following polyethylene:

1. **Low density polyethylene (LDPE):** - The oldest type. A soft, tough and flexible polyethylene type, used for strong, flexible consumer items, like screw caps and lids. For a long time already, it is also used as insulation material. At present the most popular application is foil, from which carrier bags, packaging material and agricultural plastic are made. During the high water levels in Holland in the last years, the tough strong LDPE foil served as an improvised reinforcement for the dikes.

2. **High density polyethylene (HDPE):** - This is the sturdiest and most inflexible type. Its sturdy and somewhat tough character can be used for a large range of applications. For example the well-known gft-container and a number of everyday domestic products like bottles, clothes pegs and the handle of a washing-up brush. Although HDPE is quite heavy, it can also be used for paper-thin foil that is extremely light and feels crispy. All of us use this type of foil daily; examples are sandwich bags, pedal bin bags or packaging for vegetables, fruit or meats.

3. **Linear Low Density Polyethylene (LLDPE): a mixture of both previous-mentioned types** - With this polyethylene one can go into every direction. It has some features from both of the previous-mentioned types. Both flexible and sturdy products are made from it. LLDPE is generally used in mixtures with one of the previously mentioned materials. Amongst others, even thinner foils can be produced. It is also used for multi-layer packaging. LLDPE is extremely tough and inflexible. These features can be used for the production of larger items, like covers, storage bins and some types of containers.

2.5. About Stamylex

Stamylex refers to a family of high-quality linear polyethelene[vi]. It can either be a very low-density polyethylene (VLDPE) or a high-density polyethylene (HDPE). The grade manufactured by Borealis includes 1-octene, 1-butene and propylene copolymers, manufactured using a high performance Ziegler Natta catalyst in Borealis' versatile Compact® solution polymerisation process. This grade therefore has a broad molecular weight distribution with densities greater than 915 kg/ m^3. As set out in Table 1, Stamylex is well suited for use in several broad end-use applications.

[v] The ABC of Polyethylene, available at: http://www.plasticseurope.org/information-centre/education-portal/resources-room/abc-of-plastics/the-abc-of-polyethylene.aspx

[vi] Details on Stamylex are from: http://www.borealisgroup.com/en/polyolefins/new-business-development/plastomers/

Table 1. Desirable features of Stamylex by application type

Application	Desirables features
Film applications	Stamylex blown and cast film grades cover a density range from VLDPE (910 kg/m^3) to high stiffness homopolymers (960 kg/m^3). The solution process used and the characterisation of octene polymer means that the grade of Stamylex manufactured by Borealis has the following properties: good sealing performance; superior impact, tensile and breaking strength; good optical properties with consistent low gel and impurity levels.
Moulding applications	Stamylex polyethylenes are well suited for more demanding, specialty injection moulding applications. They have narrow molecular weight distribution, high purity, good organoleptics[vii] and a broad combination of densities and melt flow indices that contributes to its uses in mineral water packaging, household products and technical articles. Products moulded from Stamylex do not exhibit warpage and are free from flow marks giving them a glossy surface.
Extrusion coating applications	Stamylex is characterised by a narrow molecular weight distribution and high purity enabling the production of films that are almost free from gels or other impurities with good organoleptic properties.

While Stamylex is technically a specialty product, it does compete against other polyethylene products that are produced using gas phase polymerisation which can fulfil the desired outcome in end products. These LDPE and HDPE products are both globally traded by producers who typically produce more than Borealis (and therefore have a larger market share). Borealis continue to produce Stamylex in part to utilise the capacity of their production site but critically because they can provide downstream users Stamylex in smaller quantities and at shorter notice. This flexibility is very important to Borealis's customers who otherwise may have to order larger quantities from other producer (which can result in less flexibility with cash flow and additional storage costs).

2.6. About Queo

Queo is a LLDPE with a narrow molecular weight distribution and a density between 860 kg/m^3 and 902 kg/m^3. It is considered to be a specialty product. In contrast to Stamylex, Queo cannot be produced from a gas phase polymerisation process. It can only be made via a solution process. There are only two producers in the EU market making a similar specialty LLPE product, which is the solution process used by [redacted].[14]

Queo made in Geleen is used in over 400 applications mainly due to the softening and sealing properties of the product. The product produced in Geleen is both sold on the general market as well as used internally by Borealis for compounding with other plastics. Compared to Stamylex, Queo can have densities as low as 860 kg/m^3 making it soft, flexible, and sticky. These desirable

[vii] Properties as experienced by the senses such as smell, sight, etc.

characteristics allow the use of Queo in numerous non-film applications such as automotive, wires, injection moulding, compounding and grafting. Other properties possessed by Queo include low peak melting points, and narrower melting ranges for improved and controlled sealing performance even with a contaminated seal area. Queo is also tough yet maintains a soft surface and anti-slip behaviour.

Queo provides a combination of low seal initiation temperatures and a high hot tack and seal strength over a broad temperature window, which outperforms conventional sealing polymers including VLDPE’s, Ethyl vinyl acetate (EVAs), and Ionomers.

The properties of Queo enable improvements to take place in existing product ranges and an expansion into new markets. It is used for film applications, extrusion coating, sound deadening and other automotive applications, flexible sheets, wires and cables, PP (polypropylene) impact modification, injection moulded articles, synthetic corks, adhesives, caps and closures, foams.

When used in film applications, Queo contributes to enhanced package appearance. The low haze value of film produced with Queo can improve product visibility and facilitate the use of graphics. In this way, Queo helps increase the quality of the appearance of product packaging because it allows seals to be overlapped. This has been exploited in the food packaging industry for high-strength freezer films or packaging of poultry and meat with sharp bones. With respect to sealing performance, there is no significant difference between Stamylex and Queo. While Queo has additional benefits from having a narrow molecular weight distribution, Stamylex maintains good sealing performance.

Core layers of Queo have also been used to improve the tear-strength of double bubble PP films. Its favourable mechanical properties deliver significant improvements even as a minority blend component, thereby making its use relatively cost-effective.

The advantages of Queo-based thermoplastic polyolefins (TPOs) have been exploited in applications including alternatives to PVC roof sheeting, automotive interior and exterior parts, appliances and mechanical goods.

When used in the wire and cable industry, Queo provides flexible low-voltage insulation and cost-effective highly filled cable compounds.

While largely used in blends as performance modifiers for other polymers, Queo has also proven to be economically feasible in its pure form as an alternative to other thermoplastics, in rotational moulding for example. Queo has displaced PVC in marine buoys and fenders due to weight and weathering advantages in the finished product.

For all the applications that use the resulting LLDPE, alternative products are available but clients prefer LLDPE for various reasons. For film type applications, LLDPE is often chosen for its superior technical properties. For compound applications, the choice for LLDPE is based on numerous factors such as price, ease of handling, availability. A typical alternative product is synthetic rubber (e.g. Ethylene Propylene Diene Monomer - EPDM). Synthetic rubber is delivered in bales and is less convenient to process compared to LLDPE, which is supplied as grains in a plastic bag. The supply as grains in bags can represent a significant advantage for the end user over the use of rubber bales.

Queo is a trademark specific to Borealis and in the EU, Queo competes with [redacted] (the only other EU producer of a similar LLDPE) in what is referred to sometimes (and in places in this report) as the PE plastomers market. In the EU, [redacted]) provides [redacted] of the production volume for the European market ([redacted]) of PE plastomers; Borealis provides [redacted] (through its Queo product range). There is only a very small volume imported into the EEA for this type of plastomer. [redacted] the global market leader ([redacted]).[15]

The market evolution for the LLDPE (Queo) production in Geleen is positive. Several new applications for LLDPE are under development and in the future Borealis expects [redacted] (see Section 2.7 below).[16]

2.7. Borealis sales

Table 2 sets out historical sales (tonnes per year) for the period 2011 to 2015 for both Queo and Stamylex, and Table 3 sets out forecasted sales for period 2016-2024. [redacted][17]

Table 2 Borealis - Historical sales data (2010-2015)[18]

Year	Stamylex (tonnes)	Queo (tonnes)
2011	[redacted]	[redacted]
2012	[redacted]	[redacted]
2013	[redacted]	[redacted]
2014	[redacted]	[redacted]
2015	[redacted]	[redacted]

Table 3 Borealis - Forecasted sales data (2016-2024)[19]

Year	Stamylex (tonnes)	Queo (tonnes)
2016	[redacted]	[redacted]
2017	[redacted]	[redacted]
2018	[redacted]	[redacted]
2019	[redacted]	[redacted]
2020	[redacted]	[redacted]
2021	[redacted]	[redacted]
2022	[redacted]	[redacted]
2023	[redacted]	[redacted]
2024	[redacted]	[redacted]

2.8. The applied for use scenario

Under the applied for use scenario, Borealis would continue to use sodium dichromate as a corrosion inhibitor in their water/ammonia absorption cooling installation ("Line 1") at their Geleen site for the following reasons:

1. [redacted]. [redacted].[20]
2. Sodium dichromate has a proven track record within Borealis as being an excellent corrosion inhibitor meaning that Line 1 can continue to operate for the foreseeable future (i.e. next 20 years) with minimal periodic investment (which is required regardless of the technology used). To date there is no evidence of any corrosion, which is vital given Borsig installation 1 have no allowance for corrosion, and there is no evidence of an alternative corrosion inhibitor being as effective as sodium dichromate, let alone one that has a long and proven track record.
3. The volume of Sodium dichromate needed for this use is very small. The historical use is only about 60 kg over three years.
4. Sodium dichromate is used in a closed system, and as shown in the CSR, even under (unrealistic) worse case assumptions there are negligible risks to workers (cancer risks being valued at ~€1.5 over 20 years (PV), no consumer exposure, and no exposure to the environment (or man via the environment). A summary of the CSR can be found in in Section 2.8.
5. There are no suitable alternatives for Borealis for the replacement of the Annex XIV substance function (which is demonstrated in Section 3).

Under the applied for use scenario, Borealis would continue to keep on top of market trends and research on any new technologies that may emerge. Borealis would continue to use sodium dichromate as a corrosion inhibitor in their water/ammonia absorption cooling installation until there was either (i) a superior (and suitable) alternative available, or (ii) there is no longer demand for Queo and Stamylex. The evidence (within this application) supports a review period of 18 years.

2.9. Risks from continued use

Within the CSR in this AfA, a risk assessment has been performed in function of Borealis' authorisation application dossier for the following uses:

(1) The use of sodium dichromate as in-situ corrosion inhibitor in a closed water/ammonia absorption cooling system

As Article 62.4(d) of REACH stipulates that the authorisation dossier shall contain a CSR covering the risks to human health and/or the environment related to the intrinsic properties specified in Annex XIV, i.e. Carcinogenic Cat.1b, Mutagenic Cat.1b and Reprotoxic Cat. 1b properties, the CSR focuses on those endpoints.

The applicant used this information to:

- Evaluate the daily (combined) worker exposure to determine Excess Lifetime Risks. An Excess Lifetime Risk means the additional risk to fatal cancer as a result of exposure to sodium dichromate (hence Chrome VI), in comparison to the risk to the fatal risk of the same type of cancer when not exposed to sodium dichromate.
- Evaluate the daily (combined) worker exposure and determine Excess Lifetime Risks based on the Reference Dose Response Relationship for carcinogenicity published by ECHA on December 4, 2013 (RAC/27/2013/06 rev.1).
- Evaluate the risk characterization ratios with regard to the reprotoxicity effects, using the DNELs communicated by the ECHA Secretariat. The use of these DNELs allows the evaluation of adequate control.
- Demonstrate minimization of risks for the uses applied for by demonstrating that the risks related to the continued use of sodium dichromate have been minimized as far as technically and practically possible.

<u>Environmental exposure and risk assessment</u>

Environment

There are worker instructions in place to ensure there is no emission to the environmental compartments. Hence, there is no risk related to the environment.

For reason of completeness, sodium dichromate is classified as an Acute and Chronic Aquatic Toxicant Category 1 (respectively H400 & H410). But, since these endpoints are not specified in Annex XIV of the REACH Regulation, the direct effects (both on a local and regional scale) and risks to the environment resulting from environmental release do not have to be evaluated in detail in this CSR for an application for authorisation.

The overall tonnage taken into account for the exposure/risk assessment was <100 kg/year, typically 60 kg/3 years, and maximally 90 kg/yr.

Man via the environment

There are no emissions to the environment, hence exposure of man via the environment is not relevant.

<u>Human health exposure and risk assessment</u>

Minimization of exposure is demonstrated by technical means and by means of monitoring, namely the fact that the installation is a fully closed system. Furthermore, Borealis ensures that procedural systems are in place to safeguard the existing processes, and the frequency and duration of the activities are limited as much as possible. The number of activities are rare (sampling 4x/yr, topping-up 1x/3yr, maintenance 2x/yr) and the duration is short (sampling < 15 min and topping up ca. 1.5 hours and maintenance < 15min). Furthermore, during the activities, personal protective equipment is also being worn to ensure further that exposure of workers is kept to the minimum. And lastly, efficient control mechanisms are in place to monitor the exposure.

Workers

- There are no regularly scheduled (daily, weekly, monthly) activities taking place with potential for exposure of workers to sodium dichromate. Any activities that are performed, take place only sporadically (one, two or four times per year) and typically by different operators. Exposure and risks were assessed per activity, as well as for the sum of the activities of a worker during his entire shift, i.e. combined exposure.

- The risk assessment for workers is based on exposure information related to personal monitoring information for the inhalation route of exposure and MEASE modelling for the dermal route of exposure. For the different type of operators, the overall exposure and Excess Lifetime Risks were determined for inhalation exposure in relation to carcinogenic effects. With regard to reprotoxic effects, adequate control of the risks was demonstrated both for the inhalation and dermal route of exposure.

- **With regard to carcinogenicity**: The overall exposure and Excess Lifetime Risks were determined for each worker type (for inhalation), taking into account that these activities only take place once/year per operator which is considered worst case. Typically different operators perform these tasks.

Table 4 Overview of ELR and additional cancer cases per operator type

Excess Lifetime Risk per operator type	**ELRs** **1/yr on 40 yr basis***	**ELR** **1/yr on 40 yr basis***	**Frequency per yr per operator**	**Total frequency per year**	**# operators**	**Additional Cancer cases per operator type**
production operator performing the refilling activity (with PPE)	1.0×10^{-7}	1.0/ 10,000,000	1/year**	1/year**	2	$2 \times 1.0 \times 10^{-7}$ = **2.1×10^{-7}**
production operator performing the sampling activity (with PPE)	1.6×10^{-7}	1.6/ 10,000,000	1/year	4/year	4	$4 \times 1.6 \times 10^{-7}$ = **6.3×10^{-7}**
production operator performing preparations for maintenance (with PPE)	1.6×10^{-7}	1.6/ 10,000,000	1/year	2/year	2	$2 \times 1.6 \times 10^{-7}$ = **3.2×10^{-7}**

Excess Lifetime Risk per operator type	ELRs 1/yr on 40 yr basis*	ELR 1/yr on 40 yr basis*	Frequency per yr per operator	Total frequency per year	# operators	Additional Cancer cases per operator type
production operator *when* performing *both* the refilling and sampling activity on one day (with PPE)	2.6×10^{-7} (sum of 1.0×10^{-7} + 1.6×10^{-7})	2.6/ 10,000,000				

* No re-calculation was done for the number of years; these values represent ELRs for 40 years.

** A Frequency of 1x/year is a worst case assessment. The typical frequency is 1x/3years. For risk assessment purposes the worst case of 1x/year was assumed.

- **With regard to the reprotoxicity**: risk characterisation ratios were determined for the relevant activities. Both the inhalation and the dermal routes of exposure were taken into account.

Table 5 Overview of RCRs per operator type

RCR* per operator type	RCRs
production operator performing the refilling activity (with PPE)	0.00061
production operator performing the sampling activity (with PPE)	0.00029
production operator performing preparations for maintenance (with PPE)	0.00029
production operator *when* performing *both* the refilling and sampling activity on one day (with PPE)	0.00090 (sum of 0.00061 + 0.00029)

*RCR combined for the inhalation and dermal route of exposure

- Based on the RCRs presented, it can be concluded that the exposure is adequately controlled with regard to the reprotoxicity endpoint.

In conclusion

This application for authorisation meets the criteria as proposed by the EU Commission for the application for authorisation for low volume uses (volume < 100 kg per year):

- Volume < 100 kg/yr: the typical volume is 60 kg over 3 years, with a worst case maximum of 90 kg/yr;
- The volume limit covers all uses of the same substance by the same legal entity;
- The application for authorisation is made by the downstream user for his own use, not for a use down his supply chain;

- There is no consumer exposure.

However, we emphasize that **all elements with regard to CSR, AoA and SEA of a standard dossier have been handled in full in this application for authorisation**, because the Implementation Regulation for authorisation applications for uses in low quantities has not come into force at the time of submission. Moreover, this application for authorisation provides all elements required and a detailed justification for a very long review period.

Also, the CSR demonstrates that the risks related to continued use are extremely low and hence the related monetary impact to human health and environment in the socio-economic analysis is also extremely low.

We compared the outcome of the CSR with the "fit-for-purpose" criteria as presented during the EU COM/ECHA Workshop on Streamlining applications for authorisation November 17th 2015[viii]:

- **There is no consumer exposure** (cfr. C*riterion n° 1*: *No consumer exposure*)
- **The maximum Excess Lifetime Risk (carcinogenicity) for a worker is 2.6:10,000,000** which is a factor of 1,500 below the proposed *Criterion n° 2* (*Excess Lifetime Risk of all exposure groups < 4: 10,000*).
- Activities (all industrial use) only take place sporadically (one to 4 times per year)
- Maximum 8 operators are involved per year to perform the required activities.
- With regard to reprotoxicity, adequate control has been demonstrated. Indeed, the max. RCR is 0.00090, i.e. when the operator would perform both the sampling and refilling task in one day
- **There is negligible or no exposure to environment** and therefore **there is no exposure to man via the environment** (cfr. *Criterion 3*: *Excess Lifetime Risk to man via the environment < 4:100,000*).
- **The scale, also called the additional cancer cases**, **is 0.000001160** which is a factor of ca. 70,000 below the proposed *Criterion 4* (*Scale = additional cancer registrations = Σ(Excess Lifetime Risks x # people) < 0.08*[ix]*).*

Meeting the "fit-for-purpose" criteria results in a very low risk to human health and the environment and hence to a very low impact in the socio-economic analysis. It demonstrates that **the emissions are indeed minimized**. In this particular case, the extremely low risk associated with the continued use of the substance results in an impact as close as ever possible to zero (€1.5 over 20 years (PV), or ~€0.13 per year). The risk assessment is presented in detail in the CSR, while the monetaray impact assessment is explained in detail in the socio-economic analysis.

We also note that the applicant had requested an exemption for this use on the basis that there is negligible exposure. The answer to the request is still pending. Hence, the applicant has decided to submit this "safety-net" application for authorisation, in which it is demonstrated, on the

[viii] http://echa.europa.eu/news-and-events/events/event-details/-/journal_content/56_INSTANCE_DR2i/title/workshop-on-streamlining-applications-for-authorisation, presentation by Mrs. Elke Van Asbroeck

[ix] The value of 0.08 corresponds to a human health cost (assuming fatal cancer) of 400,000€ over 40 years, or 10,000€ per year.

basis of measurement data, that the exposure to workers, environment and man via the environment is indeed negligible.

We conclude that this application for authorisation constitutes **an exceptional case**, **because the risk and hence the cost to human health and environment is as close as ever possible to zero**.

3. ANALYSIS OF SUBSTANCE FUNCTION

We, the applicant, need to use the Annex XIV substance for the use specified in our application for reasons of:

1. Critical substance properties related to the desired function
2. Process and performance constraints

3.1. Description of the Borsig cooling installation

The ammonia/water absorption cooling system is a three phase process (Figure 4):

1. **Evaporation:** in this stage the low-boiling ammonia evaporates and in doing so it extracts heat from its surroundings – in this case, the heat from the monomer/solvent feed-stream to the polymerization reactor.
2. **Absorption**: the gaseous ammonia is absorbed in water. As a result, the partial pressure of the ammonia is reduced, allowing more ammonia to evaporate in the evaporation step.
3. **Regeneration:** the saturated water/ammonia liquid is pumped to a distillation tower operating at [redacted][21] where the ammonia is separated from the water by means of heat. In this case, burning of natural gas generates the heat. The ammonia is condensed with cooling water in a heat exchanger and circulated back to the evaporation unit. The liquid water is recovered at the bottom of the distillation unit and recycled to the absorption unit.

As can be understood from the description, the system is fully closed, operating either above or below atmospheric pressure. Any leakages in the system must be avoided to ensure the efficiency of the process. The process only uses a pump to transfer the water/ammonia mixture from the absorption to the regeneration step. No complex gas phase compressors are used which reduces the complexity and improves the reliability of the system.

It is important to note that the system contains both gaseous and liquid conditions, with high and low ammonia concentrations.

The water/ammonia absorption cooling system is constructed in carbon steel. Carbon steel will corrode in contact with a water/ammonia mixture especially at elevated temperatures. Typical corrosion rates of 0.6 mm/year are cited in the literature[x].

The following corrosion reaction can occur even in the absence of oxygen (anaerobic):

$$Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$$

[x] Water: Handleiding voor het gebruik van water in de industrie, pag 159, 1971, Kluwer

This corrosion process affects the metal (carbon steel) transforming the iron (Fe) into iron oxide which does not contribute to the strength of the metal. As such the corrosion process reduces the wall thickness of the piping and equipment. The walls thickness of piping and equipment is in the first instance defined by the required strength. Reducing the thickness results in a situation where the piping or equipment can no longer resist the internal pressure or the mechanical forces which act on piping and equipment. Regular inspection of the equipment can reveal this process. When such damage is detected, in most cases the installation has to be stopped for repair leading to additional maintenance costs and loss of capacity. These inspection programs never cover the full installation but are spot checks. This means that still corrosion can occur unnoticed. As a result, in case of corrosion, small leaks or even rupture of piping can occur which effectively will cause a loss of containment and release of ammonia.

A second effect of the corrosion process is the formation of hydrogen (H_2). Hydrogen is a gas which will not condensate in the heat exchanger of the absorption cooling process but will form gas pockets which effectively reduce the heat exchange surface of the heat exchangers and hence, it reduces the capacity of the absorption cooling. Hydrogen is also a very explosive gas. This means that if there is locally in the installation any corrosion with a loss of containment as a result, also hydrogen will be released.

In summary, corrosion needs to be avoided for at last 3 reasons:

1. Corrosion leads to the formation of explosive hydrogen gas, which reduces the capacity of the absorption cooling and can cause release of explosive mixtures
2. Corrosion may lead to loss of containment resulting in the emission of toxic ammonia
3. Corrosion causes damage to the installation which has to be repaired leading to additional maintenance costs and loss of capacity

To completely avoid corrosion, the system is run oxygen free and a corrosion inhibitor is added. The corrosion inhibitor interacts with the chemistry of the corrosion process and prevents the corrosion. The corrosion inhibitor used by Borealis is sodium dichromate. The main chemical reaction is:

$$Na_2Cr_2O_7 + Fe^{++} + H_2O \rightarrow Cr_2O_3 + Fe_2O_3 + 2NaOH$$

Sodium dichromate is generally recognised as the best available corrosion inhibitor for the water/ammonia medium. Because of the proven performance of sodium dichromate, the Borsig 1 installation was designed in the seventies without any corrosion allowance. This means that the thickness of the piping and vessel walls does not include any additional thickness on top of the thickness necessary to achieve the required mechanical strength of the equipment. This is only possible for systems where no corrosion is expected at all. Designing the installation without corrosion allowance minimises the use of material and optimizes heat transfer in heat exchangers (through the minimization of the wall thickness of the heat exchange surfaces).

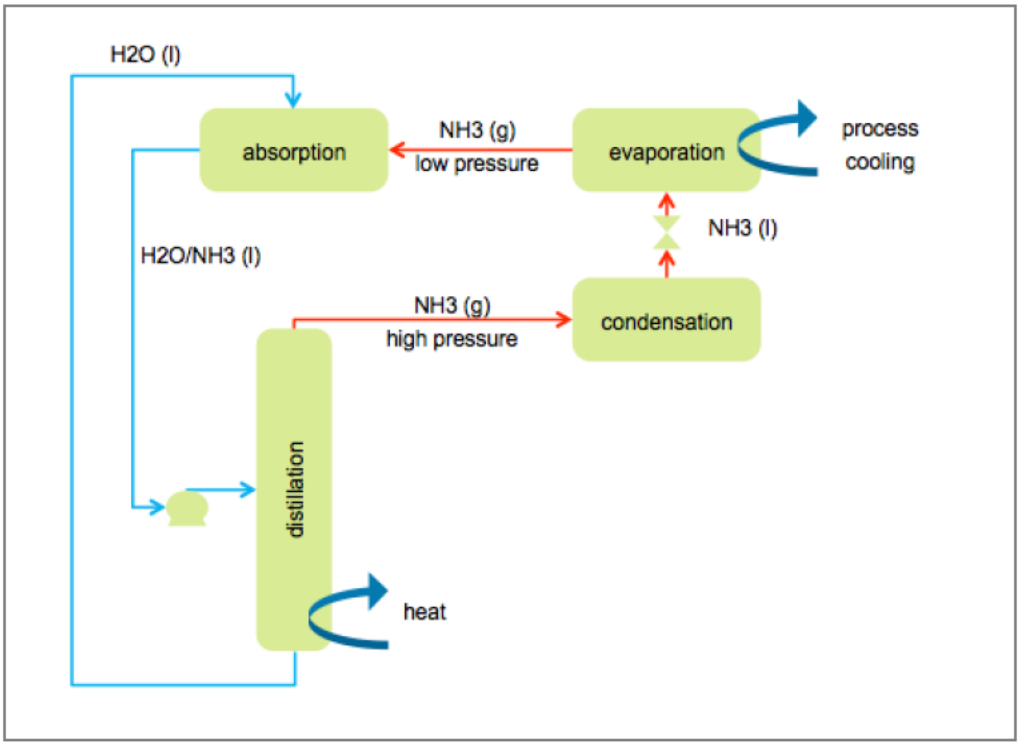

Figure 4 Absorption cooling process

3.2. Key functional requirements of the substance

The main key functional requirements are listed in Table 6.

Table 6: Key functional requirements

Property	Existing performance	Impact of deviations
Corrosion protection		
Protection of carbon steel 1 – Provide protective layer on steel (or other protection mechanism) to prevent corrosion in anaerobic conditions.	All steel types used (carbon steel) protected Full corrosion protection provided at process and flow conditions similar to current system	Reduction of strength of equipment by reduction of wall thickness. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Protection of carbon steel 2 – Sufficient corrosion protection at high pH	Corrosion protection provided at pH >7 (first condensate)	Corrosion in the area's with process conditions outside the working range of the inhibitor. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.

Property	**Existing performance**	**Impact of deviations**
Protection of carbon steel 3 – Sufficient corrosion protection in a water/ammonia system at a range of NH_3 concentrations (including first condensate)	Corrosion protection provided at concentrations of 6-100 % ammonia in water	Corrosion in the area's with process conditions outside the working range of the inhibitor. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Protection of carbon steel 4 – Sufficient corrosion protection in liquid and vapour phase	Corrosion protection provided in both liquid and vapour phases	Corrosion in the area's with process conditions outside the working range of the inhibitor. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Prevention of H_2 formation – Corrosion could result in H_2 formation which generates explosion hazard	No formation of H_2	Formation of explosive hydrogen atmosphere. The installation is not foreseen for this eventuality and any formation would have an effect
Compatibility with previous substance – Some substances could lead to increased corrosion because of incompatibility with previous use of sodium dichromate (see Appendix A)	N/A	• Insufficient corrosion protection. Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Operating conditions		
Working temperatures – Substance must be functional and stable at operational temperatures	Substance operates between [redacted] [22]	Corrosion in the area's with process conditions outside the working range of the inhibitor. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Fouling – Fouling results in a reduction of heat exchange capacity, which will reduce the production capacity.	Presently because total absence of corrosion, there is no fouling in the system	Fouling due to corrosion products (iron oxide) can cause plugging in the process and malfunctioning of valves and measurement equipment.
Operating pressure – Substance functional and stable at operational pressure	Substance is functional and stable at 12 bar	Corrosion in the area's with process conditions outside the working range of the inhibitor.

Property	Existing performance	Impact of deviations
		• Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Non-condensable gases (i.e. oxygen, hydrogen) – Non-condensable gases in the gas phase reduce heat exchange capacity, reducing production capacity	Substance results in no oxygen in the gas phase	Non-condensable gases in the gas phase reduce heat exchange capacity, reducing production capacity.
Solubility in water – Permits easy addition to the system for transport throughout the system	Inhibitor available in the full system 24hr after addition	Low solubility will affect the distribution of the inhibitor throughout the system leading to concentrations of the inhibitor below the minimum for corrosion protection. • Increased risk for explosion (due to formation of hydrogen gas) • potential uncontrolled release of ammonia. • Increased cost due to additional inspections and repair.
Operating context		
Toxicity – use toxicity should be compatible with REACH	Current substance not compatible with REACH without authorisation	To avoid authorisation requirement, substance should not be a SVHC and should not be on CoRAP as a suspected SVHC.
Commercially availability – substance should be available for use under REACH in the EU	Substance is available from a minimum of 1 EU-based supplier, and REACH Registration obligations are fulfilled	
Compatibility with current application – Density of the LLDPE polyethylene	Substance works in cooling the mixture needed for a solution polymerisation process which can achieve densities <915 kg/m^3	Production of LLDPE with densities <915 kg/m^3 by lack of solution process

3.3. Research done so far

Borealis is a downstream user of sodium dichromate as a corrosion inhibitor and, as such, has no access to specialised knowledge of corrosion processes and chemicals to prevent corrosion. For this knowledge, Borealis has to rely in the first instance on external experts and specifically on the suppliers of the corrosion inhibitors.

On two occasions in the past (2003 and 2009), the previous operators of the site investigated the possibility of using alternative corrosion inhibitors. On both occasions it was concluded that no valid alternative for sodium dichromate was known. The investigation in 2003 reported on a case where sodium molybdate was used instead of sodium dichromate. The report mentioned a failure of the system due to corrosion, with significant cost due to unexpected failure of the equipment which resulted in shutdown and required that the equipment be replaced. The absence of oxygen in the system was indicated as the cause of the corrosion, since, in contrast to sodium dichromate, sodium molybdate cannot function as a corrosion inhibitor without the presence of oxygen. This requirement for oxygen for sodium molybdate to act as a corrosion inhibitor has also been confirmed in the available literature[xi].

The investigation in 2009 consisted of a consultation with suppliers of corrosion inhibitors, suppliers of ammonia/water absorption cooling units and external corrosion specialists. These consultations confirmed the findings of 2003 that sodium dichromate was still the only available corrosion inhibitor that provides sufficient protection in the Borealis process.

Recently, experts (see appendix A) have established that traces of sodium dichromate left behind in the system can cause severe problems when changing corrosion inhibitors. At present it is unclear if an existing installation can be cleaned sufficiently of sodium dichromate to avoid this problem. These findings stress the importance of specific testing of any alternative corrosion inhibitor in circumstances relevant for the specific situation of Borealis.

To avoid the use of sodium dichromate, initial engineering work has been done by the applicant to estimate costs (investment and operational costs) to replace the current technology of ammonia absorption cooling with a compressor-based technology.

3.4. List of alternative substances / technologies

The applicant has searched for alternative substances and technologies that could replace the Annex XIV substance for the purpose of the use applied for. As a result the applicant has identified the following potential alternatives shown in Table 7.

[xi] Mechanism of corrosion inhibition by sodium molybdate; A.M. Shams El Din, Liufu Wang; Presented at the IDA World Congress on Desalination and Water Sciences, Abu Dhabi, November 18–24, 1995 (Proceedings Vol. V, pp. 181–202)

Table 7: Long list of alternatives

No:	Name	Type	Brief description (including CAS number and classification, if relevant)
1	Compressor based cooling system	Technology	Ammonia based system using compression/expansion technology for cooling.
2	$CeCl_3$ + Sodium nitrite + sodium molybdate + NaOH	Substance	Complex mixture of several substances. Mansfeld et al., Corrosion Protection of absorption heat pumps by rare earth metal salts; Research in Progress Symp., Corrosion 2001, NACE (2001)
3	Cerium Nitrate	Substance	US patent (US2002043649A1) CAS no: 10294-41-4
4	Strong base + molybdate/borate/acetate	Substance	Patent US005811026A
5	Sodium Silicate	Substance	US patent (UP005342578) CAS no: 6834-92-0
6	KOH+ KNO_3 + Zn borate	Substance	EU patent (EP1304398A2) CAS no: 138265-88-0
7	Cerium tetrahydride Sulphate + L arginine amino acid	Substance	CAS no: 10294-42-5 K.F. Khaled; Non-toxic corrosion inhibitors for steel in baseline solutions Part I EIS study Advances in Materials and Corrosion (2012) page 65-71
8	Equipment replacement	Technology	Replacement of all corrosion sensitive material (carbon steel) used in the cooling system with corrosion resistant material.
9	Inhibitor 7	Substance	This refers to a potentially suitable alternative identified in another application (Dometic). In that application, the inhibitor has always been used in a new system, which will not be the case for Borealis. Traces of sodium dichromate may interfere and cause severe corrosion problems. Suitability of this alternative certainly would need to be tested on this aspect.
10	Elastomers	Technology	Elastomers can be used to a certain extend as a replacement for PE plastomers. Elastomers are typically supplied in bales (25-30 kg) while PE plastomers are supplied as small spheres (grains). Borealis has no access to the technology to produce elastomers.

3.5. Suitability of alternatives – long list

We have assessed the alternatives listed in section 3.4 and concluded that none of the alternatives is suitable:

Table 8: Assessment of alternatives

No:	Name	Reason(s) for non-suitability	Justification
1	Compressor based cooling system	– not economically feasible – not available by Sunset Date	See details in section 3.7
2	$CeCl_3$ + Sodium nitrite + sodium molybdate + NaOH	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
3	Cerium Nitrate	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
4	Strong base + molybdate/borate/acetate	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
5	Sodium Silicate	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
6	KOH+ KNO_3 + Zn borate	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
7	Cerium tetrahydride Sulphate + L arginine amino acid	– Not technically feasible – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.9
8	Equipment replacement	– not technically feasible – not economically feasible – not available by Sunset Date – Increased risk due to potential uncontrolled ammonia exposure and explosion hazard (hydrogen)	See details in section 3.8
9	Inhibitor 7	– Not technically feasible – Not available	The nature of the alternative is unknown to us and as such not available. However, the maximum

No:	Name	Reason(s) for non-suitability	Justification
			operating temperature mentioned in the AfA of Dometic is close to the operating temperature in the Borealis installation. In the use described in the Dometic AfA, there is no prior use of chromates in the same installation. If available, the alternative would be subject to testing as described in section 3.9. However, Dometic was contacted and did not want to share the nature of the inhibitor when requested.
10	Elastomers	– not economically feasible – not available	Elastomers are generally available to the clients of PE plastomers. Nevertheless, the users of PE plastomers prefer the Borealis' products over elastomers for various reasons both technical as economic. Borealis does not operate any EPDM production facility nor has Borealis in-house access to such a technology. As such this alternative is not available to Borealis. Switching to this product would result in the closure of the Geleen site with a total loss of this business to Borealis and as such it is not an economically viable alternative for Borealis.

The classification of the substances involved in the alternatives is provided in appendix E.

3.6. Suitability of alternatives – short list

Three of the alternatives mentioned in the long list of alternatives are assessed in more detail to determine if they could be a suitable alternative. Only the alternative of using a different elastomer for the final application was not retained as Borealis has no access to this kind of technology. Two modifications of the current installation are considered: replacement of equipment and installation of compressor technology. All alternative corrosion inhibitors are assessed in a similar way since none of them has been used in an installation similar to the installation of Borealis in Geleen.

3.7. Compressor-based cooling system

In a compressor-based cooling system, the cooling is provided by the expansion and evaporation of a cooling fluid. The pressure of the cooling fluid is increased using a compressor. Borealis Geleen has already experience with an alternative cooling technology using compressors as opposed to absorption cooling. The cooling fluid would be in the compressor-based system would be ammonia, but without the presence of water and hence with no corrosion. Currently around [redacted] of total LLDPE production [redacted]) is made on a separate production line using these types of compressors.[23] This separate line was built in the eighties (1980s) to work alongside the existing absorption cooling line (which uses sodium dichromate). There would not be any significant change in the quality of the resulting LLDPE from using the compressor technology and Borealis already knows this technology works for the production of their LLDPE.

Conclusion: This alternative is considered technically feasible

The estimated (central estimate) capital cost for the replacement of the absorption cooling system is [redacted] [24] (see Appendix B for further details) based on practical experience operating this technology and a recent confidential quote (in 2015) from a supplier.

As shown in Table 9, there would be savings in operating costs from switching to using a compressor relative to the current absorption cooler, through reduced energy consumption and direct CO_2 emission costs.

Table 9: Breakdown of savings in operating costs

Aspect	Impact
Manpower:	No change
Maintenance cost:	No change
Energy cost:	Reduction of annual energy consumption due to improved efficiency of a modern system.
Direct CO_2 emission cost	Reduction in direct CO_2 emission costs by Borealis as a result of purchasing electricity rather than generating energy from direct use of natural gas.
Indirect CO_2 emissions cost	There is an increase in CO_2 emissions from the generation of electricity but as this is incorporated within the price paid for electricity these are considered to be indirect. From the applicant's perspective (i.e. not society's perspective) this is not considered further to avoid double counting of costs.

As shown in the detailed (confidential) calculations in Appendix B, despite there being some annual savings, the project has a negative return on investment (i.e. negative NPV) even after 20 years (which would in any case be considered a very long and risky project timeframe)[xii]. This conclusion is not sensitive to changes in the price of electricity, gas, CO_2, or the initial cost of the investment. As shown in Appendix B, there would have to be huge changes (improvements) in the baseline figures and assumptions in order for there to be a return on investment after 20 years. This is further compounded by the fact that there will be a loss of profits ([redacted] [25], PV, over 20 years using a 10% discount rate) within the EEA until the compressor technology would be fully operational and market share (optimistically) regained.

A sales price increase for Queo of [redacted] for 5 years would, assuming no reduction in demand from the increase, enable the investment return to be improved so that project payback over a more realistic (five-year) timeframe could be achieved. However, although Queo is a speciality product,[xiii] this is not considered a realistic scenario, as existing customers would instead either purchase a similar (to Queo) LLDPE from Asia (where there is excess supply relative to demand) or reluctantly single-source all LLDPE [redacted]. The rationale is set out in Appendix B. [26]

Customers (not just those in the EU) are very reluctant to rely on a single supplier, due to concerns over security of supply and the resulting monopolist power of a sole supplier to set prices. However this also needs to be balanced with other factors such as contractual agreements, reliability, the quality of supply available, delivery times, and overall costs. For these reasons Borealis plays an important role in the market but the demand for its Queo project is still price sensitive. As a result, an increased cost of [redacted] [27] is deemed to result in a huge reduction in sales for Borealis, loss of customers, and total profits. The reduction in profits would in turn again significantly increase the payback period for the investment. Therefore based on the analysis and knowledge of the market, the compressor technology is not an economically feasible alternative.

<u>Conclusion</u>: this alternative is not economically feasible

This technology does not use any SVHC and consists as such in a reduction in risk.

<u>Conclusion:</u> this alternative results in a reduction of risk

Although some initial engineering work has been done and a budget quote for a compressor unit is available, significant detailed engineering work is still required to define the compressor unit in detail and to design the integration of the compressor cooling system into the existing polyethylene production installation.

[xii] Note Borealis installed the compressor system (Line 2) to increase production capacity in line with increased demand for their products. This resulted in an increase in sales (and profit) which justified the investment (i.e. positive return on investment). Simply replacing Line 1 with a compressor technology with a similar capacity does not increase any production capacity and on that basis, changes in operating costs does not justify the investment (i.e. is not economically feasible).

[xiii] [redacted] [27]

The current engineering and construction plan for the compressor-based system is ca. 4 years:

- Pre-design study: define boundaries for the design of the compressor system (capacity, location, energy supply, …) → 9 months
- Engineering of new installation: detailed design of the installation to be built → 9-12 months
- Construction and commissioning of the new installation: selection of contractor, physical construction, training and start-up of installation. This estimate takes into account a certain loss in efficiency because the installation will be partially built while the existing installation is in service → 2 years

The construction of such an installation always involves the connection of the new installation to the existing installation. Such a connection can only be made when the existing installation for the production of polyethylene is stopped. It is estimated that a shutdown of at least 6 weeks will be required to connect this new installation. During this shutdown, the old cooling installation is taken out of service while the new one is connected to the ethylene production installation. After this, the production of LLDPE can only be started again with the new cooling installation.

The timing of scheduled shutdowns is defined by the frequency of regulatory inspections of pressure equipment, and these cannot be postponed. The next window of opportunity to make this connection is during the [redacted]. However, the start of such an extensive project will only occur after a formal business decision which will be based on the outcome of the application for authorisation. This means that the decision to start this project will not be taken [redacted], when a draft opinion is available. Therefore, with a four-year project horizon, it will not be possible to install prior to the sunset date. Hence, the compressor-based system cannot be considered available to Borealis at the sunset date (21/09/2017).[28]

Based on the timeline of the decision for the AfA and the time needed for engineering and construction, the earliest implementation would be after the scheduled shutdown of 2019. The earliest Borealis will be ready to connect a new cooling system to the existing system will be in Q1 2021, which would require an additional, 'on-purpose' (unscheduled) shutdown, with associated loss of production and sales. These costs have not been included in the assessment of economic feasibility of this alternative. This means that the economic feasibility in this section represents the costs in case the alternative is installed during the scheduled shutdown [redacted] [29]and not outside a shutdown window. [xiv]

<u>Conclusion:</u> this alternative is not available to the applicant by the sunset date.

[xiv] Note that this unscheduled shutdown will have no effect on the timing of the next scheduled regulatory shutdown, and hence there is no offsetting cost-saving from this additional shutdown.

3.8. Partial replacement of corrosive sensitive equipment

The operating regime of the ammonia water absorption cooling system divides the equipment into 4 types: (i) rotating equipment (e.g. pumps), (ii) static equipment (e.g. piping, heat exchangers) at low temperature [redacted] [30], (iii) static equipment at high temperature, and (iv) static equipment at medium temperature (gas and liquid phase). The corrosion regime for each of these operating ranges differs and will require different solutions. The most difficult part from the point of view of corrosion resistance is the medium temperature range where liquid ammonia and water are both present. Both rotating equipment and static equipment are used in this area of the installation. For static equipment it is expected, based on literature data, that stainless steel 316L could potentially be suitable. For rotating equipment, the replacement material has to be selected in collaboration with the equipment manufacturer. For rotating equipment the choice of the material is not only defined by the overall corrosion resistance for the fluid, but also by the mechanical and wear resistance requirements set forward by the design of the rotating equipment.

The level of corrosion resistance without the use of corrosion inhibitor needs to be established for the current equipment for the different operating regimes. The section of the process believed to have insufficient corrosion resistance will have to be replaced with equipment made of a suitable alternative material. For none of the process conditions in the Borealis absorption cooling unit have alternative materials been tested, and hence it is not known whether any such suitable alternative materials are fulfilling the technical requirements. At best literature data can be consulted. As such, the replacement of the corrosion sensitive equipment is at present not technically feasible.

Conclusion: The alternative materials are neither defined for all equipment, nor have they been tested. Hence, the alternative is currently not technically feasible.

This modification starts from a proven situation where there is no corrosion of any part of the installation. Any technical change of the installation involving a change in the selection of materials involves a risk of corrosion and hence a loss of containment of ammonia. Ammonia leakages, which can take place at any moment in time and at any location in the installation, create a serious health risk (Figure 5) which should be avoided at all times. Also explosion risk by hydrogen formation is a real risk when corrosion occurs.

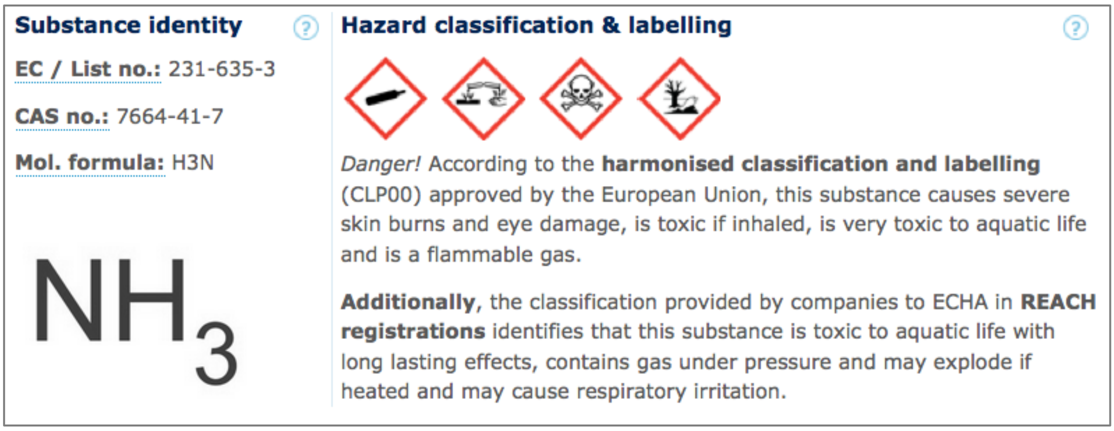

Figure 5: Classification of Ammonia (Source ECHA website)

This risk can be mitigated by careful selection and testing of the materials for construction, but there will be always a remaining risk of corrosion. This risk is both because of the limitations to effectively predict the corrosion behaviour of a metal and because inspection of the system for corrosion is a spot check. This remaining risk is taken into account by the applicant in the selection of the non-use scenario.

> **Conclusion:** The switch to an alternative construction materials has the potential to reduce risk by avoiding the use of sodium dichromate. However this alternative introduces a new uncontrolled risk since the testing of such a new corrosion inhibitor can never completely predict the corrosion behaviour of a system.

While the Borsig 1 and 2 oven sections (hot sections) are separate, the Borsig 1 and 2 absorption sections are in a common part of the installation (polymerisation reactor feed cooling). Hence it is not possible to work safely on the one part while the other part is still in operation. The replacement of the equipment will therefore require a shutdown of the complete installation (Borsig 1 and 2). The engineering and design of the alternative equipment will take 12-18 months, provided the construction materials for the different equipment have been identified and tested in relevant conditions. The selection and testing of such a materials will take at least 12 months.

A decision for the replacement of corrosive sensitive equipment will not be taken before a negative draft opinion of ECHA has been communicated. Given the time required to prepare a draft opinion by ECHA (6-9 months), the time required for the selection of the materials (>12 months) to be used and preparation of such a technical modification of the production unit (>12 months), this alternative will not be available by the sunset date of September 2017.

> **Conclusion:** this alternative is not available to Borealis at sunset date.

The cost of the replacement of the equipment is estimated at €[redacted] depending on which sections of the installation need to be replaced (details see [redacted]. [31]

The total time to install the alternative equipment is estimated at 9 weeks, which is 3 weeks longer than any scheduled production shutdown ([redacted]). The costs related to the additional downtime ([redacted]) required to install the replacement equipment is €[redacted] This means that the replacement of the equipment and the installation of a compressor involve a similar level of capital investment. However, with the replacement of the equipment there will be no saving on energy costs and there will be an additional loss of capacity and hence of revenue during the installation of the alternative. [32]

However the real cost of this replacement program lies with the uncertainty around the level of corrosion resistance achieved in the (modified) installation in the absence of sodium dichromate. In case this corrosion occurs after sunset date, such an event would cause a complete shutdown of the installation for an indefinite time until repairs are done and a solution for the corrosion problem is identified. This introduces an unacceptable business risk of which financial consequences cannot be estimated.

[xv] Hand factor estimation method using DACE (Dutch Association of Cost Engineering) data and a material factor for special grades of steel of 1.98

Conclusion: this alternative is not economically feasible.

3.9. Alternative, drop-in corrosion inhibitor

In the long list of alternatives, a number of substances are mentioned which are known corrosion inhibitors. However, none of these products has been successfully tested in conditions representative for Borealis Geleen. This means that no alternative has been proven to provide sufficient corrosion protection for the current installation. Until such testing is done with a positive outcome, these alternatives are technically not feasible.

It is important to note that part of the current installation was constructed without any corrosion allowance, since this was considered unnecessary given the (total) effectiveness of sodium dichromate as a corrosion inhibitor[xvi] (which has been proven). This means that any alternative corrosion inhibitor which provides less corrosion protection would lead to a situation where the wall thickness of the Borsig 1 installation would be sub standard and would force Borealis to take the installation out of service. Even worse, this lack of protection risks going unnoticed for a period of time during which there would be a risk of loss of containment of the ammonia.

Hence, extensive laboratory testing would be required before an alternative corrosion inhibitor could be used of even tested in the actual production site. It needs to be noted that some of the mentioned inhibitors are anodic inhibitors which could introduce an increased corrosion rate in the presence of traces of remaining sodium dichromate (see appendix A). This means that any testing needs to take into account the actual and current installation at Borealis Geleen and cannot rely only on general scientific research on this topic.

Conclusion: None of the mentioned drop-in alternatives is technically feasible.

A major concern in the development of an alternative inhibitor is to define representative test conditions in the lab which can predict the behaviour in the production unit in Geleen. For instance, as mentioned before, the tests set-up has to take into account the existing equipment has been operated for many years with a chromium-based inhibitor.

Consultation with the [redacted][33] has resulted in a possible research plan to develop the necessary tests to evaluate alternative corrosion inhibitors in conditions representative to the conditions in the production site. Such a plan (see Appendix C for details) would consist of 4 phases of laboratory testing. The deliverables of this plan would be (i) identification of a laboratory test that sufficiently imitates the conditions on site, and (ii) a list of identified corrosion inhibitors which provide sufficient corrosion protection in laboratory conditions. The next step would then be to test the corrosion inhibitor in the production site in Geleen. This testing would be done on the Borsig 2 installation only, since (1) this installation is the smallest and in case of failure it would have the least impact on the business and (2) because this installation has a minimal corrosion allowance of 1 mm. The corrosion allowance provides some level of protection in case of corrosion

[xvi] Corrosion allowance is the additional thickness of the wall of piping and equipment on top of the required thickness calculated based on the required mechanical strength.

during the test. Knowing that the typical corrosion rates is 0.6 mm/year[xvii], this means that the corrosion allowance gives a limited certainty only.
This research plan in the laboratory is estimated to take 3 years. This shall then be followed by the industrial trial which is estimated to take 3 years including preparation of the trial.

> **Conclusion:** There is no alternative corrosion inhibitor available by the sunset date for sodium dichromate.

Several of the corrosion inhibitors mentioned in the long list are less hazardous compared to sodium dichromate. However, the use of an alternative inhibitor only represents a reduction of risk if uncontrolled corrosion can be excluded. Currently there are no such tests available which can predict the behaviour of a new inhibitor in an existing ammonia absorption cooling installation. Any remaining corrosion can occur at any location in the installation, and no installation inspection can with 100% certainty find all these possible locations. This means that loss of containment of ammonia could occur at any place at any time in the installation.

> **Conclusion:** The switch to an alternative corrosion inhibitor has the potential for a lower risk from stopping the use of sodium dichromate. However this alternative introduces a new uncontrolled risk of ammonia leakage as testing can never completely predict the corrosion behaviour of a system.

As there is no alternative corrosion inhibitor currently known, it is not possible to assess the impact on the operational cost of such a switch. On the other hand the current cost of corrosion inhibitor ([redacted])[34] does not provide much room of possible financial savings using a different inhibitor.

Consultation with the [redacted] has allowed Borealis to estimate the cost of a research programme (i) to identify a suitable laboratory test and (ii) to screen existing corrosion inhibitors for their suitability. This programme has been estimated €[redacted]. This laboratory program is estimated to take minimum 3 years, which means that a plant trial cannot be started before sunset date.[35]

This then results in a risk of failure after sunset date, with no solution at hand to continue production. Hence, the real cost of this test program lies with the testing in the production site. This test has the potential to cause severe damage to the equipment potentially leading to loss of containment. This would cause a complete shutdown of the installation for an indefinite time until repairs are done and a solution to the corrosion problem is identified. This introduces an unacceptable business risk of which financial consequences cannot be estimated.

3.10. Ranking of the alternatives

Three main alternatives to be considered are:

- Replace with compressor based technology
- Replace with corrosion resistant material

[xvii] Water: Handleiding voor het gebruik van water in de industrie, pag 159, 1971, Kluwer

  - Develop an alternative inhibitor

Only the alternative where the current technology is replaced by a compressor-based technology does not introduce new risks. Both the selection of an alternative corrosion inhibitor and the use of alternative construction materials entails a risk of corrosion, loss of containment and interruption of production. As such, these alternatives are both technically infeasible currently and provide uncertain risk reduction potential. In comparison, the compressor technology is a technology known to Borealis and proven in this service. However, all alternatives are predicted to involve significant costs to adopt – including simply for the research and testing required to identify them – and none is available by the sunset date.

The identification and testing of new corrosion-resistant materials and alternative inhibitors is subject to considerable uncertainty, in terms of both success in identifying suitable candidates for adoption as well as the ultimate performance of those candidates when implemented. The business risks associated with these options – particularly the potential for a complete failure of the installation – are too great to be considered further by Borealis. As a result, if Borealis is required to stop its use of sodium dichromate by the sunset date, it will initiate a project to install a new compressor-based cooling system. This non-use scenario is described further in Section 5.

4. ANNUAL AMOUNT USED

We are using the following amount of the substance annually in the use applied for (in kg): 90 kg/year. This volume is considered a worst case scenario. In recent years, the use of sodium dichromate was 60 kg per 3 years. However, in case of a need to replace the complete inventory of water, just below 90 kg of sodium dichromate will have to be added to start the production process.

The low annual consumption is possible by means of an extremely conservative management of the installation and a multi-year optimization program. Any entrance of air is avoided and all measures are taken to capture and reuse any process liquid during maintenance.

Table 10: Tonnage sodium dichromate

Year	Purchased tonnage (kg)
2009	36*
2010	63
2011	-
2012	-
2013	-
2014	-
2015	45 + 18 = 63**
2016-2024	60 (average/3 year)
Maximum* **	**90**

**In 2009 there was major shutdown with renewal of a significant amount of water resulting in additional chromate usage.*

** [redacted] [36]

**** Maximum in case of total replacement of the water mixture within the 2 Borsig installations.*

5. NON-USE SCENARIO

The non-use scenario sets out the likely responses by affected parties if authorisation for the applied for use is refused (and therefore Borealis would need to cease use of sodium dichromate by the sunset date). This draws on the results of the AoA (Section 3) to determine the most likely response(s) along the supply chain.

5.1. Response by Borealis

Following the sunset date, Borealis would have to stop using sodium dichromate and ensure there is no sodium dichromate left in the cooling system. The Borealis site has two different cooling technologies in operation at the site. Currently [redacted] of total production (Queo and Stamylex)[redacted]) is possible through the use of a compressor system ("Line 2") that does not require sodium dichromate. After the sunset date, this cooling system will continue to be used. Since this volume [redacted]) is unaffected by the outcome of the authorisation, there are no net impacts, and Line 2 is therefore not discussed further. [37]

After the sunset date, based on the evidence presented in Section 3, it is clear that the only option available to Borealis would be to shut down Line 1 completely as it is dependent on the use of sodium dichromate as a corrosion inhibitor. It would mean the decommission of both "Borsig 1" and "Borsig 2" resulting in a significant reduction in production and associated sales revenue as Line 1 supports [redacted][38] of total production.

In order to minimise in the long term lost profits to Borealis from reduced production capacity, Borealis's only option is to replace Line 1 (i.e. the two Borsig installations) with a compressor based cooling system. Borealis would do this despite there being a negative NPV (i.e. after 20 years using a 10% discount rate) using a compressor, as it is the only technically feasible alternative known at this stage and it thus provides Borealis with the only realistic certainty of continued production (and crucially profit from sales) similar to under the applied for use scenario.

Some pre-engineering work would commence prior to the sunset date (in Q2 2017) but the timing would ultimately depend on when the final decision is made by the European Commission (EC). If the ECHA committees propose to grant authorisation but the EC's final decision is to refuse authorisation, Borealis will only begin planning for a compressor technology after a final decision the EC. Equally if the ECHA committees final opinion proposes to refuse authorisation, Borealis will only begin planning for a compressor technology based on a draft opinion by the ECHA committees but will not commit to any significant investment until a final decision is made by the European Commission.

As set out in Section 3.7 it is estimated that it will take at 3-4 years from the start of the engineering before a compressor system can be operational. To install such a system, a shutdown time of at least 6 weeks is estimated to be required. The non-use scenario responses for Borealis are summarised below in Figure 6 whereby the analysis takes an optimistic perspective by assuming that the compressor cooling unit will be fully operational by Q1 2021.

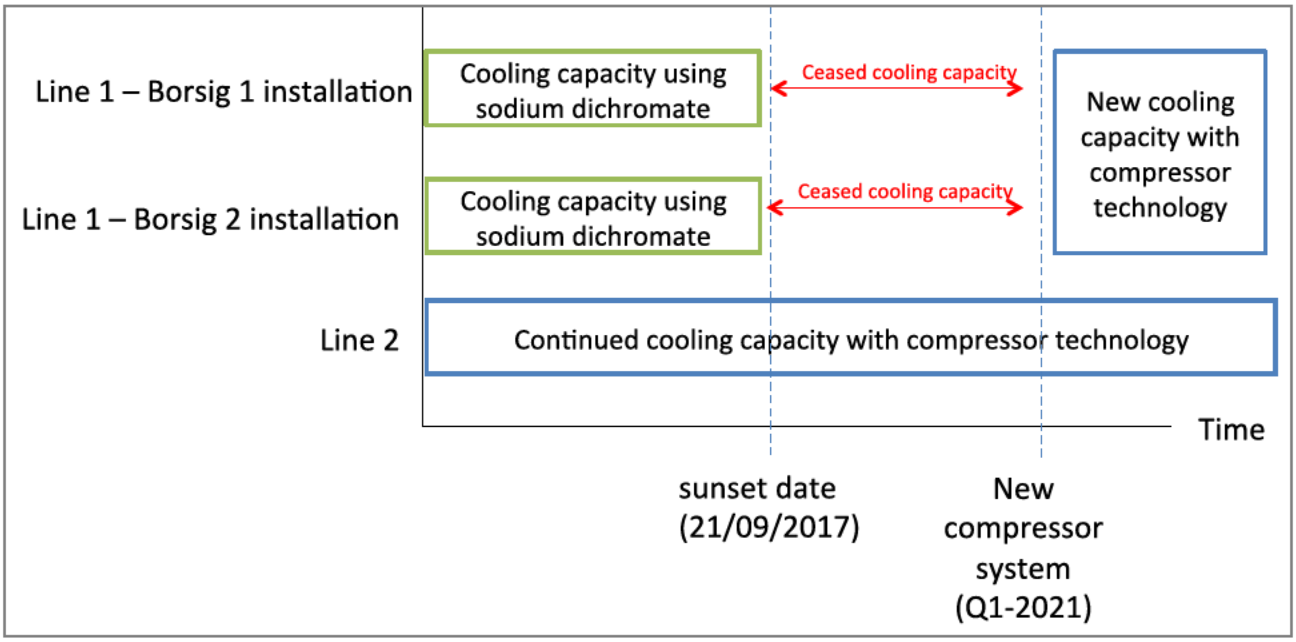

Figure 6: Borealis non-use scenario

5.2. Response by other polyethylene suppliers

It is estimated that any lost sales of Stamylex in the short term at least will be displaced by either LDPE or HDPE depending on the applications. Some of these may be supplied by EU based suppliers but the exact share is not possible to estimate. However for lost Queo, as explained earlier in Section 2, in the EU there is only one other LLDPE supplier [redacted]. [redacted] the (global) market leader and accounts for [redacted] of the European market ([redacted]) for PE plastomers; Borealis provides [redacted] If Borealis is unable to produce as much Queo, the most likely outcome is that Borealis's reduction in supply will be offset by increased production by either [redacted] or through increased sales from Asian based suppliers, as there is excess supply of LLDPE in Asia (i.e. Supply > demand) and based on internal data available these suppliers are actively seeking to gain a presence in the EU market for LLDPE.[39]

5.3. Response by downstream users of Queo and Stamylex

Based on communications with existing customers (by Borealis) and existing knowledge of the market, the most likely outcome is that most downstream users would seek additional supply from a similar supplier rather than switch away from LLDPE (given its specific desirable properties). In the case of Queo, to ensure security of supply (i.e. not be reliant on just one supplier) and to ensure that there is sufficient competition amongst suppliers, the majority of Borealis's customers are likely to follow their current strategy and unlikely to purchase significantly more from [redacted].[40] Therefore many end-users are expected to deliberately purchase LLDPE from Asia from multiple suppliers (in different quantities and times) rather than a single supplier.

6. ANALYSIS OF IMPACTS

6.1. Introduction

The aim of this Section is to determine if the benefits of continued use of sodium dichromate for this very specific use outweighs the risks to human health and the environment. This is done by comparing the impacts from the applied for use scenario with the non-use scenario. The changes in impacts (often referred to as the 'net' impacts,) form the basis of the cost-benefit analysis (CBA) and stem from changes in consumer prices, producer profits, and risks to the environment and human health (e.g. due to work place exposure)[xviii]. An overall positive net impact would mean that authorisation is justified from the overall perspective of society. A negative net impact would indicate that society is better off if authorisation were refused.

Impacts were screened to determine those to be assessed within this section. This screening exercise is included as an appendix (Appendix D) to show to interested parties and the SEA Committee (SEAC) that a wide range of impacts were considered and any justification for not assessing them further.

The assessment focuses on the EEA, as recommended in the ECHA SEA guidance. The analysis takes a very optimistic view that Borealis can regain any lost market share due to a refused authorisation 3 years after the new compressor cooling unit is operational in Q1-2021. Therefore the assessment focuses on all relevant impacts between 2017 and 2024. After 2024, the impacts under the applied for use and non-use scenario as expected to be similar (i.e. no net impact) except energy savings associated using the new compressor cooling unit which are assessed over a 20 year period (a 20 year period is consistent with the SEA guidance).

[xviii] It is important to note some key caveats about the scope of the analysis that can be practically undertaken to support the SEA. Formally – in terms of the underlying principles of economic analysis – the CBA should be based on changes in consumer and producer 'surpluses'. Consumer surplus is the difference between what a consumer is willing to pay to purchase a product and the price they actually pay. Producer surplus is the difference between the price received for a product and the minimum they would be willing to sell it for (typically represented by the marginal cost of production). In combination, the combined net change in consumer and producer surpluses (the 'economic surplus') represents the genuine change in overall social welfare perspective that the SEA is concerned with; hence if product prices or production costs change as a result of a refused authorisation, there are consequential changes in economic surpluses along the supply chain. However, data to calculate these changes in economic surplus are often not readily observable (e.g. information on average and marginal costs of production are confidential to upstream suppliers and downstream users). Hence the analysis that supports a SEA is typically based on financial flows (e.g. sales revenue, profits, operating costs) from which changes in social welfare may be inferred. In many instances this is an appropriate approach as it is sufficient to demonstrate the balance of impacts in terms of order of magnitude (i.e. whether the risks to human health and the environment from continued use outweigh the benefits of authorisation, or vice versa).

6.2. Human health or environmental impact

Based on the screening of health impacts, the only health impact deemed necessary to assess (although not deemed significant) is worker inhalation exposure to sodium dichromate. As described in the CSR, a total of 8 workers are potentially exposed to very low levels of sodium dichromate a few times a year (or in some cases once every 3 years) for the following activities:

1. During refilling: presence of 2 operators 1 time/3years, but for the risk assessment a worst case of 2 operators 1 time/year is considered,
2. Sampling: presence of 1 operator 4 times/year, typically a different operator for every occasion. This can thus also be described as 1 operator exposed 1x/year and this for in total 4 operators, and
3. Maintenance: presence of 1 operator 2 times/year, typically a different operator for every occasion. This can thus also be described as 1 operator exposed 1x/year and this for in total 2 operators.

The exposure would either continue in the applied for use scenario or cease in the non-use scenario. As a worst case estimate, for consistency with the CSR it is assumed the workers performing the refilling activity are exposed once every year.

To quantify the additional number of lung cancer deaths from worker exposure the dose response relationship report provided by ECHA was used for carcinogenicity. For the lung cancer calculation, Excess Lifetime Risk (ELR) is defined as the additional or extra risk of dying from cancer due to exposure to a toxic substance incurred over the lifetime of an individual. Note that developing cancer may occur during working life or after retirement. The linear exposure-risk relationship for lung cancer as estimated by ECHA is given by:

Unit occupational excess lifetime mortality risk $= 4 \times 10^{-3}$ *per µg Cr(VI)/*m^3

This excess risk estimate is measured up to the age of 89, based on assumed exposure of eight hours per day for five days per week over a working life of 40 years is assumed. The risk assessment in this application for authorisation is based on there being no thresholds for cancer effects of sodium dichromate for lung cancer using a presumed exposure of 8 hours per working day over a working life of 40 years. For reprotoxicity adequate control has been demonstrated in the CSR (RCR is 0.00090). Hence, because there is no risk related to this endpoint, reprotoxicity is not further discussed in the SEA.

The total ELR was calculated in the CSR (and is also shown in Section 2.9 - risks from continued use) based on the excess lifetime mortality risk and the number of workers affected. The total ELR as shown in Table 11 is extremely small under both the best estimate (where PPE is used) and even under a sensitivity whereby PPE is not used. The numbers both with and without PPE, are reported as the exposure was determined based on actual personal exposure measurements which do not take into account the PPE, although the operators always wear the relevant PPE during the described activities. Table 11 also shows that the costs of fatal lung cancers from worker inhalation exposure estimated at €1 (PV) over 20 years. Based on these results, it can be concluded that the cancer mortality risks are negligible (i.e. €1).

Table 11: Estimated value of fatal lung cancers from worker inhalation exposure

	Total excess lifetime risks (over 40 years)	Value of a fatal cancer (2015 prices)	Total value of fatal cancers (€, 40 years)	Total value of fatal cancers (€/year)	Total value of fatal cancers (20 years (PV)
Realistic estimate - With PPE	0.00000116	€ 3,696,000	€ 4	€ 0.11	€ 1.3
Sensitivity - Without PPE	0.0000231	€ 3,696,000	€ 85	€ 2.13	€ 26

Notes:

1. PPEs are always worn during the activities (standard operational procedure).
2. See CSR for details of how the excess lifetime risks were determined. Excess risk is measured in absolute terms, not percentage points, and is linear, i.e. proportional both to individual exposure and to persons exposed. Therefore, exposures can be treated as 'separable' over time (i.e. the risk for one year is equal to 1/40 of the risk over 40 years), and exposures of different persons can be added. Note also that, because of the specification of the dose-response functions, no differences in baseline cancer risks (e.g. between men and women, between different EU Member States or between different age groups) affect the estimation of incremental cancer deaths. Therefore, neither the share of male and female workers exposed at work or a location nor the exact ages of workers influence the outcome of the estimations.
3. Value of a fatal cancer was taken from the ECHA (2014) study - Stated-preference study to examine the economic value of benefits of avoiding selected adverse human health outcomes due to exposure to chemicals in the European Union.
4. Prices are in 2015 prices. The original ECHA value (€3.5million was uplifted to 2015 prices using a GDP inflator of 1.056).
5. Present Value (PV) are based on a 4% discount rate as per the ECHA SEA guidance and a base year of 2016

The individual development of cancer diseases may be fatal or non-fatal, whereas the exposure-response functions employed are defined in terms of cancer mortality only. Therefore, the excess risk of cancer is higher than the excess risk of cancer mortality estimated via the exposure-response functions. This is important when applying the ECHA guidance on Socio-Economic Analysis (2011) in order to ensure that the total number of cancer cases is correctly estimated and appropriately valued. What defines a non-fatal cancer is not simple since the risk of cancer recurrence blurs the boundary between separate cancer incidents. Thus, non-fatal cancer is most appropriately defined in terms of survival. According to Cancer Research UK, 'disease-free survival' is defined as being alive and health, with no recurrence, five years after initial diagnosis.[xix] This definition also matches the availability of national cancer survival statistics from the Eurocare project (www.eurocare.it).

According to the Netherlands Cancer Registryxx the number of people surviving lung cancer after 5 years is 17%. This means that for every fatal lung cancer in the Netherlands, there is an additional 0.2 non-fatal cases (=0.17/(1-0.17)). Using this information, Table 12 sets out the costs of non-fatal

[xix] http://www.cancerresearchuk.org/about-cancer/what-is-cancer/understanding-cancer-statistics-incidence-survival-mortality#dfs

[xx] http://www.cijfersoverkanker.nl/selecties/Dataset_1/img56e031463a1d0

lung cancers from worker inhalation exposure estimated at €0.2 (PV) over 20 years. Based on these results, it can be concluded that the cancer non-fatal risks are also negligible (i.e. €0.2).

Table 12: Estimated value of non-fatal lung cancers from worker inhalation exposure

	Total non-fatal cancer risk (over 40 years)	Value of a non-fatal cancer (2015 prices)	Total value of non-fatal cancers (€ - 40 years)	Total value of non-fatal cancers (€/year)	Total value of non-fatal cancers (20 years) (PV)
Realistic estimate - With PPE	0.0000014	€ 432,960	€ 1	€ 0.02	€ 0.2
Sensitivity - Without PPE	0.0000278	€ 432,960	€ 12	€ 0.30	€ 4

Notes:

1. PPEs are always worn during the activities (standard operational procedure).
2.
3. Value of a non-fatal cancer was taken from the ECHA (2014) study - Stated-preference study to examine the economic value of benefits of avoiding selected adverse human health outcomes due to exposure to chemicals in the European Union.
4. Prices are in 2015 prices. The original ECHA value (€0.41million was uplifted to 2015 prices using a GDP inflator of 1.056).
5. Present Value (PV) are based on a 4% discount rate as per the ECHA SEA guidance and a base year of 2016

Combining the estimated fatal and non-fatal cancer risks as reported in Table 11 and Table 12 respectively gives a best estimate of €1.5 (PV over 20 years). Based on these results, it can be concluded that the health risks from continued use are negligible. The fact that some health and environmental impacts which were deemed not to be significant were not assessed would not change this conclusion. In fact, the environmental costs increased transportation emissions due to imports for LLDPE into the EU would far outweigh the risks of worker exposure.

6.3. Economic impacts of refused authorisation

Based on screening possible impacts of a refused authorisation (see Appendix D – Table D.1) the main impacts are expected to be the:

- Net cost to Borealis of new compressor system to replace the current Line 1 (Capital costs less savings in operating costs); and
- Lost profit to Borealis from additional downtime in production.

There are also further negative economic impacts associated with a refused authorisation noted in Table D.1 which were deemed to not be significant enough to warrant assessing further but collectively further add to the scale of the negative economic impacts.

6.3.1. Net cost to Borealis of new compressor system

As set out in the non-use scenario, Borealis would invest in replacing Line 1 (Borsig installation 1 and 2) with one new compressor system. With pre-planning starting before the sunset date, it is optimistically assumed that construction would start in 2018 and the compressor operational by Q1 2021. As set out in Appendix B, the capital cost of this investment is estimated at €[redacted] million ([redacted] – PV using a 4% discount rate).[41]

The main advantage of using the compressor system is that Borealis can return to similar production capacity as it knows that it is technically feasible given that Line 2 is already using a compressor system. There is also the additional annual savings from reduced energy consumption and avoided direct costs of CO_2 emissions (from avoided use of gas as incurred under the applied for use scenario); both of which are desirable also from society's perspective.

Over a 20 year period (2017-2036) based on Line 1 operating at maximum capacity of (i.e. assuming full capacity) after Q1-2021, the net present value (NPV) is negative and estimated at -€1.4million – using a 4% discount rate as per the SEA REACH guidance[xxi]. Therefore even using a discount rate that reflected society's perspective, this investment is not deemed a good investment (see confidential excel file submitted with this application for further details on the supporting calculations).

The -€1.4million NPV estimate is based on the plant operating at full capacity from Q1-2021. This assumes there are no production delays, no gradual build up to full production capacity and ignores that it will take Borealis several years to potentially gain its original market share. Therefore in reality the NPV is likely to be worse than the -€1.4million estimate. As a sensitivity analysis of other variables, the investment in the compressor technology could be considered beneficial if there were a permanent 1.6% higher increase in gas prices relative to electricity prices, as then there would be a slight positive NPV of €0.1million. However on balance the evidence suggests that the estimate of -€1.4million NPV is a conservative estimate rather than a pessimistic estimate (given the number of optimistic assumptions used).

6.3.2. Lost profit to Borealis (and within the EU)

Under the non-use scenario there will be a loss in Borealis's production, leading to a reduction in sales revenue and profit to Borealis. Until the new compressor system is operational in Q1-2021, Borealis would try to minimise any lost profit by significantly reducing production of Stamylex (after a negative draft opinion by ECHA) to focus production to make extra Queo (a more valuable product) prior to the sunset date on Borsig installation 1 and 2.

Forecasted sales under the applied for use scenario (as shown earlier in Table 3) and the non-use scenario were estimated (see confidential excel file submitted with this application for further

[xxi] In order to value CO_2 emission, Borealis has used business projected CO_2 prices over the next 30 years based on the price of traded EU allowances. This is deemed suitable for the SEA as the ECHA SEA guidance states that "it is suggested to use an estimate of the cost based on the abatement costs. Policies such as the EU Emissions Trading likely to set a cap on the total emission, which means than action that increases or decreases CO_2 emissions will not impact on total EU level of emissions".

details on the supporting calculations), with the loss in sales (i.e. net between the applied for use scenario and non-use scenario) presented in Table 13.

Table 13: Lost sales (tonnes) over the period 2017-2024 [42]

Type of product	Unit	TOTAL (2017-2024)
Stamylex	Tonnes	[redacted]
Queo	Tonnes	[redacted]

Table notes:

- Figures take into consideration production up to the sunset date (September 2017). The analysis stops at 2024 as it is optimistically assumed that Borealis would regain its market share (similar to the applied for use) a few years after the new compressor new is operational (in Q1 2021). In reality, there could be a permanent or a much longer recovery period.
- A breakdown of lost sales per year is provided in the confidential excel file provided to ECHA.

Table 14 estimates lost revenue based on lost sales shown above and the current 2015 average price for Queo and Stamylex (i.e. no forecasting of future prices). The total loss of sales revenue is estimated at €[redacted][44] million (PV).

Table 14: Lost sales revenue (€ million) over the period 2017-2024 [43]

Type of product	Unit	TOTAL (2017-2024)	TOTAL NPV (2017-2024)	
Stamylex	€million	[redacted]	[redacted]	[redacted]
Queo	€million	[redacted]	[redacted]	

Table notes:

- Figures take into consideration production up to the sunset date (September 2017). The analysis stops at 2024 as it is optimistically assumed that Borealis would regain its market share (similar to the applied for use) a few years after the new compressor new is operational (in Q2 2021). In reality, there could be a permanent or a much longer recovery period.
- A breakdown of lost sales revenue per year is provided in the confidential excel file provided to ECHA.
- Based on a 4% discount rate as per the ECHA SEA guidance and a base year of 2016.

Although the effort required is disproportionate given the small volume of the substance used and negligible human health risks, there is a clear requirement from ECHA to focus on the direct costs associated with a refused authorisation, such as lost profit and the cost of substitution (where relevant), as it could be argued that a reduction in production could also result in reduced operating costs for labour and raw materials. With respect to costs of labour, Borealis do not plan to make any significant redundancies given workers will be required for testing the new compressor plant and once it is be operational. Therefore the profits margins used are an underestimate because they deduct the total costs of employment whilst in practice a part of these costs would still be incurred under the non-use scenario.

The ECHA authorisation guidance (ECHA 2011[xxii]) indicates that "gross profit of a substance or a product is the difference between the sales revenue and the variable and fixed costs of producing the product. Fixed and variable costs (also known as "cost of goods sold") include e.g. materials and labour. Gross Profit = Revenue - variable costs - fixed costs".

The average gross profit margin ([redacted]) was provided by Borealis but is subject to fluctuations (both up and down) based on a number of factors such as the price of product and demand relative to supply. These factors are largely driven by the market leader ([redacted]) rather than Borealis.[44] However for the purposes of this SEA, the average gross profit margin value is deemed sufficient rather than presenting a wider range for lost profits (i.e. ranges within different scenarios) given difficulties in forecasting future prices. Applying this percentage, Table 15 estimates that if authorisation were refused, Borealis could lose a potential profit of ~€[redacted] million (PV) over the period 2017-2024.[46]

Table 15: Lost profit (€ million) over the period 2017-2024 [45]

Type of product	Unit	TOTAL (2017-2024)	TOTAL NPV (2017-2024)	TOTAL NPV (2017-2024)
Stamylex	€million	[redacted]	[redacted]	[redacted]
Queo	€million	[redacted]	[redacted]	

Table notes:

- Figures take into consideration production up to the sunset date (September 2017). The analysis stops at 2024 as it is optimistically assumed that Borealis would regain its market share (similar to the applied for use) a few years after the new compressor new is operational (in Q2 2021). In reality, there could be a permanent or a much longer recovery period.
- Based on a 4% discount rate as per the ECHA SEA guidance and a base year of 2016.

EU based downstream users of the LLDPE ('Queo') would also be affected by any loss in production of Queo. They would either have to increase their orders from [redacted] other EU supplier or import a similar LLDPE from outside the EEA. To ensure there is security of supply and further strengthening the power for one supplier to set prices, most EU downstream users are likely to start to import a similar LLDPE from Asia rather than rely [redacted].[46]

Therefore most profits identified would be lost to suppliers to Asia rather than retained within the EU-28 under the applied for use scenario. It is optimistically assumed that Borealis can regain its market share by 2024 but in practice there could be a permanent loss in profits even once the new compressor system comes on line if importers gain a presence on the EU market. Again this would depend on a number of factors such as the reliability of their supply, quantitates available, the price, and quality of their LLDPE.

xxii (ECHA 2011) - Guidance on the preparation of an application for authorisation, Version 1, January 2011: http://echa.europa.eu/documents/10162/13643/authorisation_application_en.pdf

6.4. Social impacts

Based on screening possible impacts of a refused authorisation (see Appendix D – Table D.4) the main social impact identified was the downstream user loss in availability of Stamylex from Borealis. The advantage of purchasing from Borealis is the flexibility, intrinsically related to the solution technology used by Borealis, offered to small downstream users who are able to purchase Stamylex in small volumes and at short notice for niche applications. This flexibility may not be available if they have to purchase a similar product from other suppliers who apply large scale technology which is less flexible to change grades and to produce small volumes. Without further consultation it is not clear how significant any costs such as issues on reduced cash-flow and/or the need for bridging loans might be.

As noted above Borealis would seek to retain some production staff to ensure a smooth transition to the new compressor system but there will be some staff that would be made redundant. There would be a cost to Borealis (redundancy package) and costs to the staff being made redundant, from temporary unemployment (i.e. until they can find another job), changes in job satisfaction (if their new job is not as enjoyable / fulfilling), changes in net disposable earnings (e.g. their new job may pay more or less, involves more travel time/cost), and emotional costs associated with losing their job (e.g. stress and anxiety).

6.5. Comparison of costs and benefits

Table 16 summarises the key monetised costs and benefits of granting authorisation. It is clear when comparing the negligible health costs (best estimates of €1.5 PV over 20 years) of continued use to the economic and social benefits of continued use that society would be better off if authorisation were granted. Any uncertainties or key variables used in the analysis are not sensitive enough to affect the conclusion that the benefits of authorisation outweigh the risks of continued use.

Table 16: Comparison of costs and benefits of authorisation (PV, over 20 years)[47]

Type of impact	Benefits of authorisation	Costs of authorisation	Net impact
Economic	Avoided capital cost of compressor cooling unit [redacted]	Higher energy ([redacted]) and CO_2 costs ([redacted]) of using existing Line 1 cooling unit (compared to use of compressor technology)	Net benefit of €1.4million
	Avoided lost profit to Borealis of €[redacted] million	-	Net benefit of up to [redacted] million
Human health	-	Limited worker exposure (best estimate of €1.5	Negligible
Environmental	No significant benefits	No significant costs	-
Social	Continued availability to downstream users of Stamylex and Queo from Borealis	-	Net social benefit
	Avoided redundancies due to downtime until new compressor is operational		
Macro-economic	No significant benefits	No significant costs	-

Notes:

1. Based a 4% discount rate and 2015 prices
2. See confidential excel file for supporting calculations to these numbers,

7. INFORMATION FOR THE LENGTH OF THE REVIEW PERIOD

Based on the evidence presented in this application, Borealis is seeking a review period of 18 years as it meets what the ECHA (2013)[xxiii] guidance on setting a review period refers to as an 'exceptional' case.

Borealis uses sodium dichromate in a closed system and as the CSR clearly demonstrates even under (unrealistic) worse case assumptions that:

- There is no consumer exposure;
- There are negligible risks to workers (cancer risks valued at ~€1.5 PV over 20 years which are effectively as close to zero as feasible);
- No exposure to the environment;
- No exposure to man via the environment; and
- The typical volume used (60 kg/3 yrs) is minimal and has been minimized by optimising the product process.

With minimal periodic investment (which is required regardless of the technology used), Line 1 can continue to operate well beyond the next 20 years. Borealis therefore have no long term plans to change Line 1 because:

1. The market is expected to grow over the next 10 years (forecasting beyond this is very difficult) and this would require the full capacity available of Borealis Line 1 and 2;
2. There are no suitable alternatives for Borealis for the replacement of the Annex XIV substance function. Borealis would continue to research new technologies but currently there are no new/emerging technologies (e.g. cooling equipment, cooling technologies or superior products) that Borealis are aware of that will be available within the next 18 years.
3. Past research has not lead to a suitable alternative. Any further research in-house would cost €[redacted] [48], which is not proportionate to the minimal impact of €1.5 to human health and environment.
4. There is a long and proven track record of producing Stamylex and Queo using sodium dichromate as an in-situ corrosion inhibitor in a closed water/ammonia absorption cooling system. To date there is no evidence of any corrosion, which is vital given Borsig installation 1 have no allowance for corrosion, and there is no evidence any alternative corrosion inhibitor being as effective as sodium dichromate, let alone one that has a long and proven track record.
5. Borealis has invested significant time and resources in ensuring worker safety. As the risks are negligible, it does not make financial sense to invest significant amounts of money on any known (unsuitable) alternatives.

[xxiii] (ECHA 2013) – "Setting the review period when RAC and SEAC give opinions on an application for authorisation". Available at: https://echa.europa.eu/documents/10162/13580/seac_rac_review_period_authorisation_en.pdf

6. As demonstrated in the non-use scenario, it is not in societies best interests for Borealis to replace Line 1 with a compressor cooling system as even after 20 years any energy and CO_2 savings do not outweigh the initial investment costs. This is further compounded by the fact that there will be a loss of profits within the EEA until the compressor technology would be operational. Relative to the risks of continued use (€1.5 PV over 20 years) it is clear that such an investment is not justified as there could be more productive uses of that investment in the future (i.e. projects that return a positive NPV).

The evidence presented in this application clearly shows that the risks are negligible whilst the socio-economic benefits of continued use are high ([redacted]).[49] There is therefore no justification from a risk perspective to give a shorter review period than 18 years (i.e. risks are valued at ~€1.5 over 20 years which would negligible change if authorisation was given for 12 years).

It would also not be beneficial to grant a shorter review period than 18 years as there is not foreseen to be a different applied for use position. Even a review period of 12 year (whilst defined as ‘long’ in the ECHA guidance note) would be too short a review period as there are no new/merging technologies (known at this stage) which hypothetically could be tested and be operational commercially (for a long period of time) to justify Borealis investing money to change their existing Line 1 system. Even then, the technology would have a high (and quick) return on investment for Borealis to want to invest it rather than reapply for authorisation.

Therefore other than an update on the market (e.g. demand and any info on alternatives), it would simply result in Borealis reapplying for authorisation rather than indicating a switch in technology. There would be no change in the non-use scenario and therefore ECHA would effectively be making a decision for authorisation based on the same information as already provided within this application.

Taking into consideration all of the information presented in the application, the evidence clearly justifies this application for authorisation being considered an exceptional case with a review period of 18 years.

8. CONCLUSION

The key findings of this Application for Authoristion (AfA - made up of the Chemical Safety Report – CSR, Analysis of Alternatives – AoA, and Socio Economic Analysis – SEA) are:

1. The risks are minimised:
    a. There is no consumer exposure to sodium dichromate from products made;
    b. There are negligible risks to workers;
        i. Lung cancer risks are valued at less than two euros in total over 20 years
    c. No exposure to the environment; and
    d. No exposure to man via the environment; and
    e. The typical volume used (60 kg/3 yrs) is minimal and has been minimized by optimising the product process.
2. There are no suitable alternatives to Borealis Plastomers BV (the applicant)
3. The socioeconomic benefits of continued use estimated at ~€[redacted] [50] (–PV, over 20 year).
4. The evidence demonstrates that the benefits of continued use far exceed the risks to human health and the environment.
5. The evidence also demonstrates the case for a review period of 18 years.

The results are clear and justify this application being considered an **"exceptional case"** warranting a review period longer than 12 years which is currently defined as a "long" review period, in part because the **cost to human health and environment is as close as possible (feasible) to zero.**

Appendix A EXPERT STATEMENT ON ACCELERATED CORROSION RATE IN THE PRESENCE OF TRACES OF SODIUM DICHROMATE

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04/11/2015

A corrosion inhibitor is a chemical additive, which, when added to a corrosive aqueous environment, reduces the rate of metal wastage. There are two main types of inorganic inhibitors: cathodic and anodic.

During the corrosion process, the **cathodic corrosion inhibitors** prevent the occurrence of the cathodic reaction of the metal. These inhibitors have metal ions able to produce a cathodic reaction due to alkalinity, thus producing insoluble compounds that precipitate selectively on cathodic sites. Deposit over the metal a compact and adherent film, restricting the diffusion of reducible species in these areas.

Anodic inhibitors (also called passivation inhibitors) act by a reducing anodic reaction, that is, blocks the anode reaction and supports the natural reaction of passivation metal surface, also, due to the forming a film adsorbed on the metal. In general, the inhibitors react with the corrosion product, initially formed, resulting in a cohesive and insoluble film on the metal surface. **Sodium dichromate** belongs to this category of anodic inhibitors.

For the anodic inhibitors effect, it is very important that the inhibitor concentrations should be high enough in the solution. Concentrations below to the critical value are worse than without inhibitors at all. The inappropriate amount of the inhibitors affects the formation of film protection, because it will not cover the metal completely, leaving sites of the metal exposed. This situation can become a serious problem due to the oxidising nature of the inhibitor which raises the metal potential and encourages the anodic reaction. These sites can give rise to localised attack, generating pitting corrosion, due reduction at the anodic area relative to cathodic, or can accelerate corrosion, like generalized corrosion, due to full breakdown the passivity.

Other examples of anodic inhibitors include orthophosphate, nitrite, nitrates, ferricyanide, molybdates, hydroxides and silicates.

References

[1] National Physical Laboratory UK. *A short introduction to corrosion and its control.* Available from : www.npl.co.uk/upload/pdf/basics_of_corrosion_control.pdf

[2] Materials Science "Developments in Corrosion Protection", book edited by M. Aliofkhazraei, ISBN 978-953-51-1223-5, Published: February 20, 2014 under CC BY 3.0 license. *Chapter 16 Corrosion Inhibitors – Principles, Mechanisms and Applications.* By Camila G. Dariva and Alexandre F. Galio. DOI: 10.5772/57255.

[3] Passivity breakdown and pitting corrosion of binary alloys. Nature 350, 216-219 (21 March 1991) | doi:10.1038/350216a0; Accepted 14 February 1991. Available from: http://www.nature.com/nature/journal/v350/n6315/pdf/350216a0.pdf

Appendix B ECONOMIC FEASIBILITY OF COMPRESSOR TECHNOLOGY

This appendix sets out further details to support why the compressor technology is not economically feasible. The confidential excel file along with this application provides all the supporting calculations so that the SEAC can verify the analysis presented in this appendix. The information is deemed commercially sensitive and therefore the majority of this appendix, included the excel file should be treated confidentially.

Confidential supporting analysis [51]

[redacted]

[redacted]

[redacted]

52

[redacted]

[redacted][52]

[redacted]

[redacted][52]

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

[redacted]

[redacted]

[52]

As the investment results in a negative NPV, this would be considered a very poor investment from the firms' perspective and introduces unnecessary risks to the business. There would have to be huge variations in order for there to be a return on investment after 20 years.

A sales price increase for Queo of [redacted][53] for 5 years would, assuming no reduction in demand from the increase, enable the investment return to be improved so that project payback over a more realistic (five-year) timeframe could be achieved. However, although Queo is a speciality product,[xxiv] this is not considered a realistic scenario, as existing customers would instead either purchase a similar (to Queo) LLDPE from Asia (where there is excess supply relative to demand) or reluctantly single-source all LLDPE [redacted].[53] The rationale is set out below:

[redacted].[52]

Customers (not just those in the EU) are very reluctant to rely on a single supplier, due to concerns over security of supply and the resulting monopolist power of a sole supplier to set prices. However this also needs to be balanced with other factors such as contractual agreements, reliability, the quality of supply available, delivery times, and overall costs. For these reasons Borealis plays an important role in the market but the demand for its Queo project is still price sensitive. As a result, an increased cost of [redacted] [53] is deemed to result in a huge reduction in sales for Borealis, loss of customers, and total profits. The reduction in profits would in turn again significantly increase the payback period for the investment. Therefore based on the analysis and knowledge of the market, the compressor technology is not an economically feasible alternative.

[xxiv] Borealis's Stamylex product is in competition with bulk suppliers which means that Borealis has little market influence, so a price increase for Stamylex is not considered a realistic way of improving the return on the compressor investment.

Appendix C REQUIREMENTS FOR A DEVELOPMENT PROGRAM FOR A NEW CORROSION INHIBITOR

Such an R&D project needs to be split in 2 main steps:

- Step 1 is the research on laboratory scale.
- Once a successful candidate is identified, then a plant trial will be made (Step 2).

As explained before, all possible actions need to be taken to assure the same level of corrosion protection of an alternative inhibitor compared to the current one. Testing with an alternative inhibitor without proper lab testing has been tried before with severe results (cost and risk of emission of ammonia).

Hence a main challenge in the identification of a suitable alternative corrosion inhibitor is to identify the specific conditions of corrosion in the plant and to simulate these in lab conditions. To achieve this, tests have to be designed. These conditions of corrosion relate to process temperature, pressure, composition of the cooling fluid, current status of the metal surfaces and flow conditions. The latter is of specific importance as the mechanism of corrosion protection is the formation of a protective layer. The stability of this layer is affected by the erosion. Erosion is caused by the flow of the cooling fluid itself. Especially bends and other area of high turbulence could be vulnerable to accelerated corrosion.

The concept of the plan is a two-step evaluation of commercially available corrosion inhibitors. In the first step less sophisticated tests are used to screen a larger number of candidates. In a second stage, lower number of substances are tested in more realistic process conditions which simulate the real installation.

This appendix describes the phases and related timelines for the research on laboratory scale (i.e. for Step 1). This program is made based on consultation with the [redacted][53]

<u>PHASE 1: Literature and contacts (Duration ~6 months)</u>

- o Detailed literature and patent screening
- o Detailed definitions of the different corrosion environments in the Borsig system
- o Identification test candidates
- o Establishing contacts and collaborations with suppliers, other users and stakeholders

<u>→Milestones in this phase:</u> State of the art overview, List of test candidates

<u>PHASE 2: Test method (Duration ~9 months)</u>

- o In the cooling installation different conditions for corrosion can be found such as in the gas an liquid phase as identified in the first phase. These different conditions may lead to different corrosion mechanisms. For each of these conditions, the conditions and the constraints for the test set-up need to be defined.

- Definition of test methods: based on the constraints and conditions in the real plant, the test set-up needs to be defined to simulate each of these conditions.
  Once the design of the test set-up is made (potentially different set-up will be required to simulate the different conditions), equipment needs to be purchased and installed.
- The new equipment will be tested with preliminary tests to assure the correct functioning of the equipment.
- Definition of test plan: Timing and deliverables of the test program are documented

→ Milestones in this phase: Test equipment ready, Definition of Test methods, Test plan for screening of candidates

PHASE 3: Screening (Duration ~10 months)

- Procurement of test candidates
- Definition of success criteria for the screening (which substances to be take in next phase) and fixed conditions for benchmarking
- Screening (short term tests) of test candidates for different scenarios (gas phases, liquid phase, diff. concentrations etc.)
- Selection of best performing candidates
- Alignment with stakeholders (Borealis site, R&D group, Borealis innovation group, corporate HSEQ and product stewardship) and suppliers about feasibility
- Interpretation of results
- Draft of detailed test approach

→ Milestones in this phase: Selection of best performing candidates, Draft of detailed test approach

PHASE 4: Detailed Testing (Duration ~14 months)

- Identification and definition of detailed test scenarios: during this phase a limited number of substances will be tested in detail. The different conditions in the plant need to be simulated in the different test set-up as defined in earlier phases.
- Set-up detailed test plan
- Detailed testing
- During detailed testing, the of corrosion/protection mechanism for the different test substances will be identified; performance of the test substances and consumption rate will be established.
- Selection of preferred candidate
- Alignment with stakeholders (Borealis site, R&D group, Borealis innovation group, corporate HSEQ and product stewardship) and suppliers about test results
- Interpretation and summary of results
- Draft of plant test approach
- The current installation is using sodium dichromate as corrosion inhibitor. It is likely that the R&D plan will identify that there is an effect of the use of sodium dichromate on the proper functioning of a new corrosion inhibitor. To avoid this effect, the R&D plan will define a procedure to clean the current installation.

→ ***Milestones in this phase:*** Selection of preferred candidate, proposal for plant test, finishing of technical report

The cost of the research plan (laboratory phase only!) is estimated to [redacted].[54]
The outcome of the R&D-project would be a proposal for a plant test. This plant test will be organised in an own follow up project with an estimated duration of 3 years.

Appendix D SCREENING OF IMPACTS

As set out in the ECHA SEA guidance, for proportionality the assessment of impacts should focus on the key costs and benefits (i.e. those that could influence the outcome of the SEA). This Appendix shows the screening exercise undertaken to select those impacts considered in detail in Section 5. It also provides some supporting analysis as to why some identified impacts were deemed not significant enough to assess in quantitative and/or monetary terms.

D.1 Economic impacts

Table D.1 lists the main types of economic impacts expected based on the most likely responses to a refused authorisation (as set out in Section 5.2).

Table D.1 Screening of economic impacts

Supply chain	Description of the impact	Likely to be significant impact?	To be assessed in detail?
Sodium dichromate manufacturers	Lost profit from reduced sales	The amount of sodium dichromate purchased every 3 years is very small (60 kg) and therefore any loss in sales would result in a small loss in profit to sodium dichromate manufacturers.	No
Raw materials suppliers	Lost profits within the EU from reduced demand for raw materials used by Borealis during temporary downtime	Borealis will increase production prior the sunset to mitigate any possible reduction in supply to customer. Therefore there is unlikely to be a significant impact on upstream suppliers.	No
Borealis	Capital cost of new compressor cooling system	The capital cost [redacted][54] noted in the AoA is deemed a significant cost	Yes
Borealis	Savings in operating costs of using a compressor cooling system	The energy savings noted in Appendix B are deemed a significant saving	Yes
Borealis	Lost profit from additional downtime in production	The scale of downtime is uncertain as it will depend on the success of building a new compressor cooling system by mid-2021.	Yes
End-users	Functioning of / competition within the	Due to additional downtime by Borealis there will be some potential reduction in supply. This may have impact on the	Yes – qualitative assessment

Supply chain	Description of the impact	Likely to be significant impact?	To be assessed in detail?
	EU market	functioning of the EU market given there is only one other EU based supplier for LLDPE. Due to uncertainties and because there are more tangible costs that can be assessed, it is deemed disproportionate to assess this impact beyond a qualitative assessment.	

D.2 Human health risks

Table D.2 lists the main types of human health impacts expected based on the most likely responses to a refused authorisation (as set out in Section 5.2).

Table D.2 Screening of human health impacts

Supply chain	Description of the impact	Likely to be significant impact?	To be assessed in detail?
Worker exposure at Borealis site	There are [redacted][55] workers that would no longer be exposed to sodium dichromate.	No - given the volume used. But since risks to human health are the reason why sodium dichromate has been placed on Annex XIV it should be assessed in detail.	Yes
General population around the Borealis site	Potential exposure of the general population around the site (man via the environment).	No - given the fact that there is no exposure of man via the environment as there is no environmental release.	No
Consumer exposure from products made with LLDPE	Potential exposure of consumers.	No – given the fact there is no contact whatsoever between the sodium dichromate and the final product (LLDPE).	No
EU general public	Respiratory impacts from increased transportation emissions of similar LLDPE into the EU.	Unknown - given the total volumes expected to be imported this is not expected to be a significant impact.	No

D.3 Environmental risks

Table D.3 lists the main types of environmental impacts expected based on the most likely responses to a refused authorisation (as set out in Section 5.2). Based on the screening exercise there are no environment impacts deemed significant enough to warrant assessing in the SEA.

Table D.3 Screening of environmental impacts

Compartment	Description of the impact	Likely to be significant impact?	To be assessed in detail?
Local air	Increase from direct emissions from the absorption cooling unit.	No – given the fact that there is no environmental release.	No
Local water supply	Increase from direct emissions from the absorption cooling unit.	No – given the fact that there is no environmental release.	No
Waste	Increase from waste containing sodium dichromate (water/ammonia/sodium dichromate mixture)	No – given the fact that the waste will be treated by an external specialised facility for hazardous waste treatment.	No
CO_2 emissions	Increase from indirect emissions from energy consumed using compressor technology	The indirect costs of CO_2 emissions are already accounted for in the price Borealis would have to pay for electricity.	No
GHG emissions	Increases in GHG emissions from transportation of LLDPE from outside of the EU	Unknown, but given the total volumes of LLDPE expected to be imported, this is not expected to be a significant impact	No

D.4 Social impacts

Table D.4 lists the main types of social impacts expected based on the most likely responses to a refused authorisation (as set out in Section 5.2).

Table D.4 Screening of social impacts

Type of impact	Description of the impact	Likely to be significant impact?	To be assessed in detail?
Employment	Loss of employment due to additional downtime.	No as there is not expected to be any lots of redundancies. Some workers may be made redundant whilst other workers may be used to help minimise and mitigate where possible delays in the building of the new compressor.	No - Relative to other impacts such as lost profit this is not deemed necessary to assess
Downstream user choice and availability	Loss of Stamylex supply by Borealis.	Due to prioritising increased production of Queo, Borealis would no longer supply Stamylex on the market. This would reduce downstream user choice and availability of smaller volumes.	No – qualitative assessment only

D.5 Macroeconomic impacts

Table D.5 lists the main types of macroeconomic impacts expected based on the most likely responses to a refused authorisation (as set out in Section 5.2). It is not uncommon that no significant macroeconomic impacts are identified (which is also reflected in the ECHA SEA guidance).

Table D.5 Screening of macroeconomic impacts

Type of impact	Description of the impact	Likely to be significant impact?	To be assessed in detail in final SEA?
Gross Domestic Product (GDP)	Loss in output would affect NL and EU GDP.	No, given that the scale of output lost relative to EU-28 GDP. (€13.9 trillion in 2014[xxv])	No
Trade balance	Worse EU trade balance as there will be a reduction in EU exports (sales of Queo to non-EU countries) and an increase in imports (of similar LLDPE) into the EU from countries outside of the EU.	No, given the size of EU trade balance.	No

[xxv] http://ec.europa.eu/eurostat/tgm/refreshTableAction.do;jsessionid=MmhlPclIgz2EgNxAwf2Fo8qJDmexBSk_31taQcvXXWODfhAYP9ob!-1393835901?tab=table&plugin=1&pcode=tec00001&language=en

Appendix E LIST OF ALTERNATIVES

This appendix list all alternatives discussed in the AoA-SEA.

Number	Name	CAS	Classification
1	Compressor based cooling system (ammonia)	7664-41-7 (ammonia)	Press. Gas Flam. Gas 2 Skin Corr. 1B Acute Tox. 3 Aquatic Acute 1
2	$CeCl_3$ + Sodium nitrite + sodium molybdate + NaOH	7790-86-5 (cerium trichloride)*	Skin Corr. 1C Eye Dam. 1 Aquatic Acute 1 Aquatic Chronic 1
		7632-00-0 (sodium nitrite)	Ox. Sol. 3 Acute Tox. 3 Aquatic Acute 1
		7631-95-0 (sodium molybdate)*	Not classified
		1310-73-2 (sodium hydroxide)	Skin Corr. 1A
3	Cerium nitrate*	10294-41-4	Ox. Sol. 2 Eye Dam 1
4	Strong base + buffer (molybdate/borate/acetate)	1310-73-2 (sodium hydroxide)	Skin Corr. 1A
		1310-58-3 (potassium hydroxide)	Acute Tox. 4 Skin Corr. 1A
		21351-79-1 (cesium hydroxide)*	Acute Tox. 4 Skin Corr. 1A Eye Dam. 1 Repr. 2
		1310-65-2 (lithium hydroxide)*	Acute Tox. 4 Skin Corr. 1B
		7631-95-0 (sodium molybdate)*	Not classified
5	Sodium silicate	6834-92-0	Skin Corr. 1B STOT SE 3
6	KOH + KNO_3 + Zn borate*	138265-88-0	Eye Irrit 2 Repr 2 Aquatic Acute 1 Aquatic Chronic 2
7	Cerium tetrahydride	10294-42-5	Skin Irrit 2

Number	Name	CAS	Classification
	sulphate + L-arginine amino acid		Eye Irrit 2 STOT SE 3
8	Equipment replacement	n.a.	n.a.
9	Inhibitor 7**	Confidential	Eye irrit. 2A Acute Tox. 3 Aquatic Acute 1
10	Elastomers	n.a.	n.a.

* No harmonised classification

** Taken from Joint Analysis of Alternatives and Socio-Economic Analysis (non confidential report) on sodium chromate by Dometic GmbH.